Preliminary Assessment of the Occurrence and Biological Effects of Cadmium, Lead, Manganese and Zinc in the Short Creek/Empire Lake Aquatic System, Cherokee County, Kansas

by

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ABSTRACT

Analysis of 70 Ekman dredge samples collected 26-27 May 1987 from Empire Lake reservoir in Cherokee County, Kansas indicates that concentrations of cadmium, lead, manganese and zinc are elevated in sediments throughout the lake. Concentrations of cadmium, lead and zinc were highly correlated and reached highest concentrations in the shallow common area of the reservoir between the Spring River and Shoal Creek arms. Manganese was negatively correlated with cadmium and had highest average concentrations in the Spring River arm. Cadmium concentrations ranged from undetectable (one sample) to 49.8 ppm, with 80% of the samples having 10 or more ppm. Lead concentrations ranged from 9.28 ppm to 341.5 ppm, with 83% having 100 or more ppm. Manganese concentrations ranged from 293.7 ppm to 1370 ppm, with 75% having 500 or more ppm. Zinc concentrations ranged from 100 ppm to 5503 ppm, with 94% having 1,000 or more ppm. ANOVA indicated that manganese showed a highly significant added component of variance due to depth, with average concentrations increasing up to depths of 6 meters. Concentrations of cadmium, lead and zinc showed no relationship to depth.

Thirty-eight taxa of aquatic insects were collected, representing the orders Ephemeroptera, Megaloptera, Odonata and Diptera. Several Oligochaeta species were also collected. The family Chironomidae was the most abundant and species rich taxon, representing 68.5 of the specimens collected and 71% of the taxa. Oligochaeta and <u>Hexagenia</u> sp. were also abundant, with 14.4% and 8.2% of total specimens collected, respectively. There was a distinct depth effect observed with regard to species richness and standing crop densities, with maximum values for both observed at the 1-2 meter depth. Richness and density declined at deeper depths. No relationship was seen for metals concentrations and richness or density when all 70 samples were analyzed irrespective of depth. When sorted by depth class a significant negative relationship was observed for species richness and standing crop densities versus concentrations of lead, zinc and cadmium for depths less than one meter. A positive relationship was seen for density and the concentrations of cadmium, lead and zinc at depths greater than one meter but less than two meters. Manganese showed a positive relationship to species richness and standing crop density at depths greater than two meters but less than 3 meters.

Densities of aquatic macroinvertebrates versus depth and position in the reservoir were low and only exceeded 1,000 per square meter at one site. Comparisons with literature values showed that standing crop densities of macroinvertebrates of Empire Lake reservoir are lower by a factor of 10-100 than densities estimated for other reservoirs with good water quality and lacking high concentrations of heavy metals in sediments. No significant difference was observed with regard to species richness. It is concluded that the main effect of high concentrations of cadmium, lead and zinc in the sediments of Empire Lake is reduction of the standing crop density of aquatic macroinvertebrates.

KEYWORDS: Cadmium, Lead, Zinc, Manganese, Heavy Metals, Reservoir Sediments, Benthic Macroinvertebrates, Sediment Criteria, Species Richness, Standing Crop Density.

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INTRODUCTION

Nature of the Problem

Southeastern Kansas is a region noted for its concentration of mineral resources. Much of Crawford County and to a lesser extent portions of Cherokee County have been and remain an area of rather extensive coal mining (Anonymous, 1978). In contrast, however, the lead and zinc mining area of Kansas was confined to the very southeastern corner of Cherokee County (Figure 1). This area combined with adjacent regions of southwestern Missouri and northeastern Oklahoma was mined for nearly 100 years, and in the recent past was one of the most productive centers for lead and zinc ores (Clark, 1970).

Depletion of known concentrated reserves, combined with the discovery of new high grade ores elsewhere, caused declining production and ended large scale lead and zinc mining activities by 1970 (Anonymous, 1980). In Kansas the most intensified lead-zinc mining activities were confined to an area occupying about 2,000 acres of land surrounding the town of Galena. To date only limited attempts have been made to reclaim the mined area, and most of the 2,000 acres still exist as huge areas of concentrated lead and zinc pilings from milling activities or as waste materials from smelting operations.

Short Creek and its tributaries and a small unnamed stream drain most of the areas where pilings and other waste materials are accumulated (Figure 2). As a result of surface runoff, flooded mine drifts and shafts, and groundwater seepage the water quality of the above streams has been substantially degraded. The degradation is so severe that concern has been expressed about

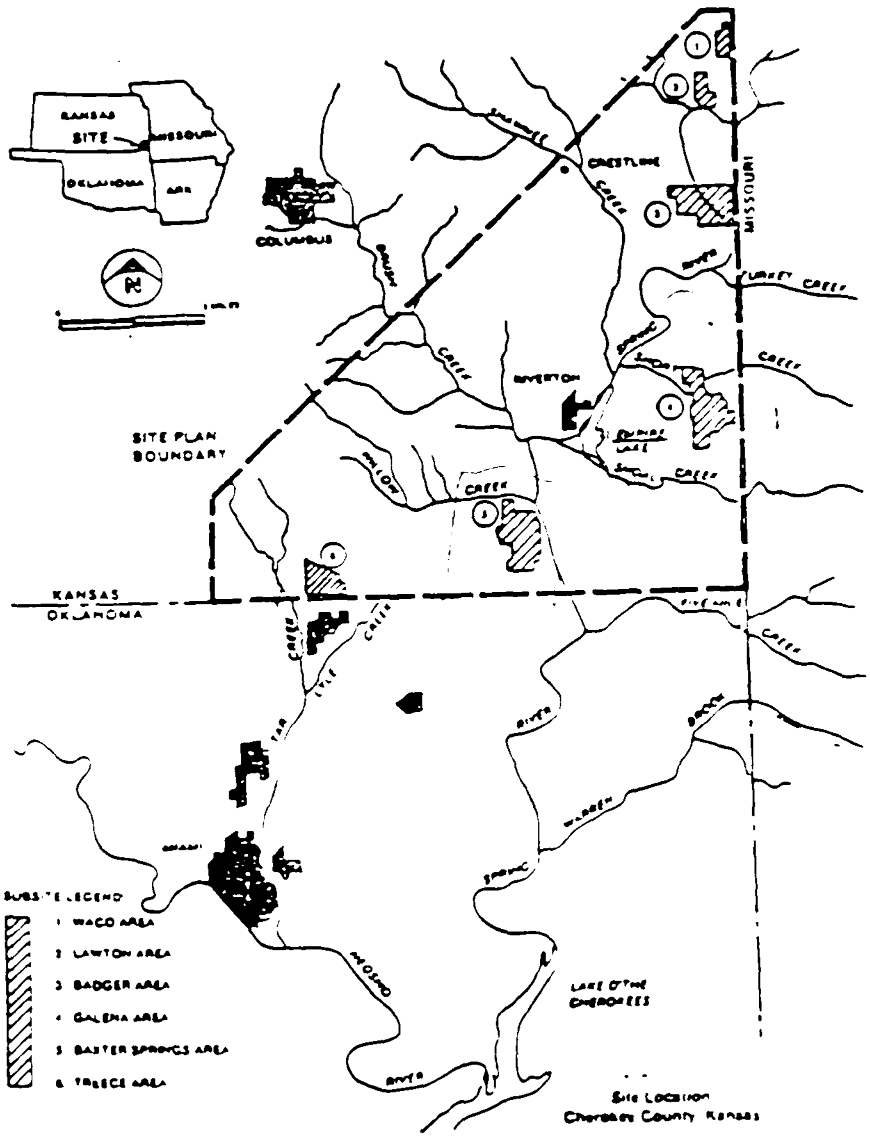

Figure 1. Site locations for lead and zinc mined areas in Cherokee County, southeastern Kansas. Map reproduced from U.S. EPA report of June 10, 1985 (Annonymous, 1985).

the threat that this water quality deterioration poses to present and future water resources in the area. For instance, Spruill (1984) has estimated that 673 pounds per day of Zinc and 4.57 pounds per day of Cadmium are being transported in the lower reaches of Short Creek, and most or all of this transport load ends up in Empire Lake.

Short Creek and an unnamed tributary flow west from the mined area and confluence with the tail waters of Empire Lake. The Spring River and its drainage system in Kansas (including Shoal Creek) have one of the most diverse sport fisheries in the State (Cross and Collins, 1975). In addition, several rare, unique, threatened or endangered species of fish, amphibians and invertebrates are restricted to this basin in Kansas (Collins, 1982; Platt et al., 1974). Therefore further water quality deterioration in the lower section of the Spring River drainage in Kansas could have a severe negative effect upon the distribution and abundance of the unique biota of the area.

Because of the diverse sport fisheries in the Spring River drainage, Empire Lake and the area surrounding it serve as a major recreational focus for the region. There is substantial development of cottages and summer homes around the lake, and several of these homes have lake frontage, complete with boat docks and swimming areas. In consideration of the potential threat to aquatic biota and of possible human health hazards posed by movement of heavy metals into Empire Lake, it has been our feeling that research efforts need to be made to investigate the accumulations of cadmium, lead, zinc and manganese in the substrates and biota of the reservoir.

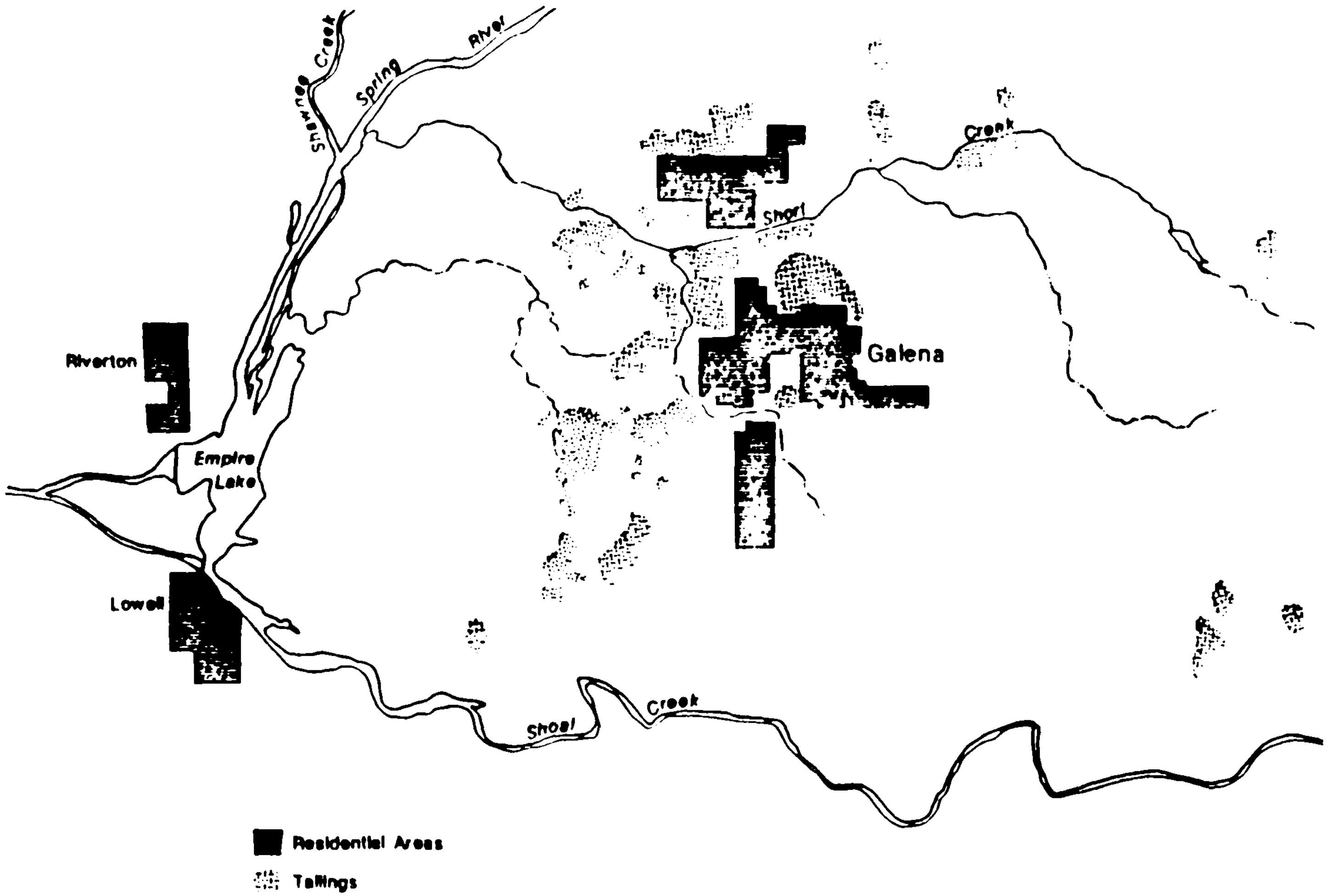

FIGURE 2: Relationship of Galena mining area to Empire Lake reservoir.

Objectives of the Research

The following set of objectives were proposed for this research project: (1) Determine the concentrations of cadmium, lead, zinc and manganese in samples of substrates from control and impacted areas in Empire Lake. (2) Determine the species richness, relative abundances and estimate standing crop densities of aquatic macroinvertebrates in samples of substrates from control and impacted areas of Empire Lake. (3) Develop by multiple regression analysis a series of empirical models that relate the extirpation of species and/or decreases in standing crop densities of macroinvertebrates to specific concentrations of heavy metals in reservoir sediments. (4) Develop a series of recommendations, based upon empirical data, that can be used to set sediment/heavy metal criteria to protect X percentage of the Empire Lake benthic biota. (5) Determine the whole body burdens of cadmium, lead, zinc and manganese from selected species of aquatic organisms from different trophic levels or functional groups within the Empire Lake system. (6) Assess the potential for biomagnification of cadmium, lead, zinc and/or manganese within the food chains.

Results of objectives number 1, 2 and 3 are presented in this report. Research continues with regard to objectives 4, 5 and 6, and will be presented in subsequent reports.

Several factors have been shown to effect the distribution and abundance of aquatic macroinvertebrates in lentic situations. Most important among these are dissolved oxygen concentration, depth of water and particle size composition of sediments. In order to gain some understanding of the behavior of these parameters it was necessary to perform vertical profiles of oxygen and temperature and to measure the depth at the sites which were preselected for sampling. These data are also included and discussed in this report.

SITE DESCRIPTION AND SAMPLING AREAS

Empire Lake is situated just east of Riverton, Kansas and is formed by water backed up by two dams (figure 3). The Riverton Dam is located in the river bed of the Spring River and the Lowell Dam is located just south, in the river bed of Shoal Creek. Water is backed up in the river channels by the respective dams for distances of several miles, and to a height that is sufficient to inundate much of the land that previously separated the two river channels in the area immediately east of the two breastworks. For reference purposes we have divided the reservoir into 4 distinct regions, which are indicated on figure 3 and shown in more detail in figures 4-6. These areas consist of the Spring River arm of the reservoir, the Shoal Creek arm of the reservoir, the common area of Empire Lake and the breastworks area.

In our original design the intention was to establish a series of transects in the two arms of the reservoir and to take pairs of samples in shallow areas near each bank and a pair of samples from the deepest portion of transect near the center of the arm. In a previous report to EPA (Anonymous, 1985) it was stated that preliminary sampling from the Spring River arm indicated that the sediments of this arm consisted largely of fine organic muds and clays. Based upon this report, we felt that it would be relatively straight forward to sample these types of sediments using the Standard Ekman dredge sampler and planned accordingly. It was also our intention to generate vertical profiles of water temperature and dissolved oxygen at each of the

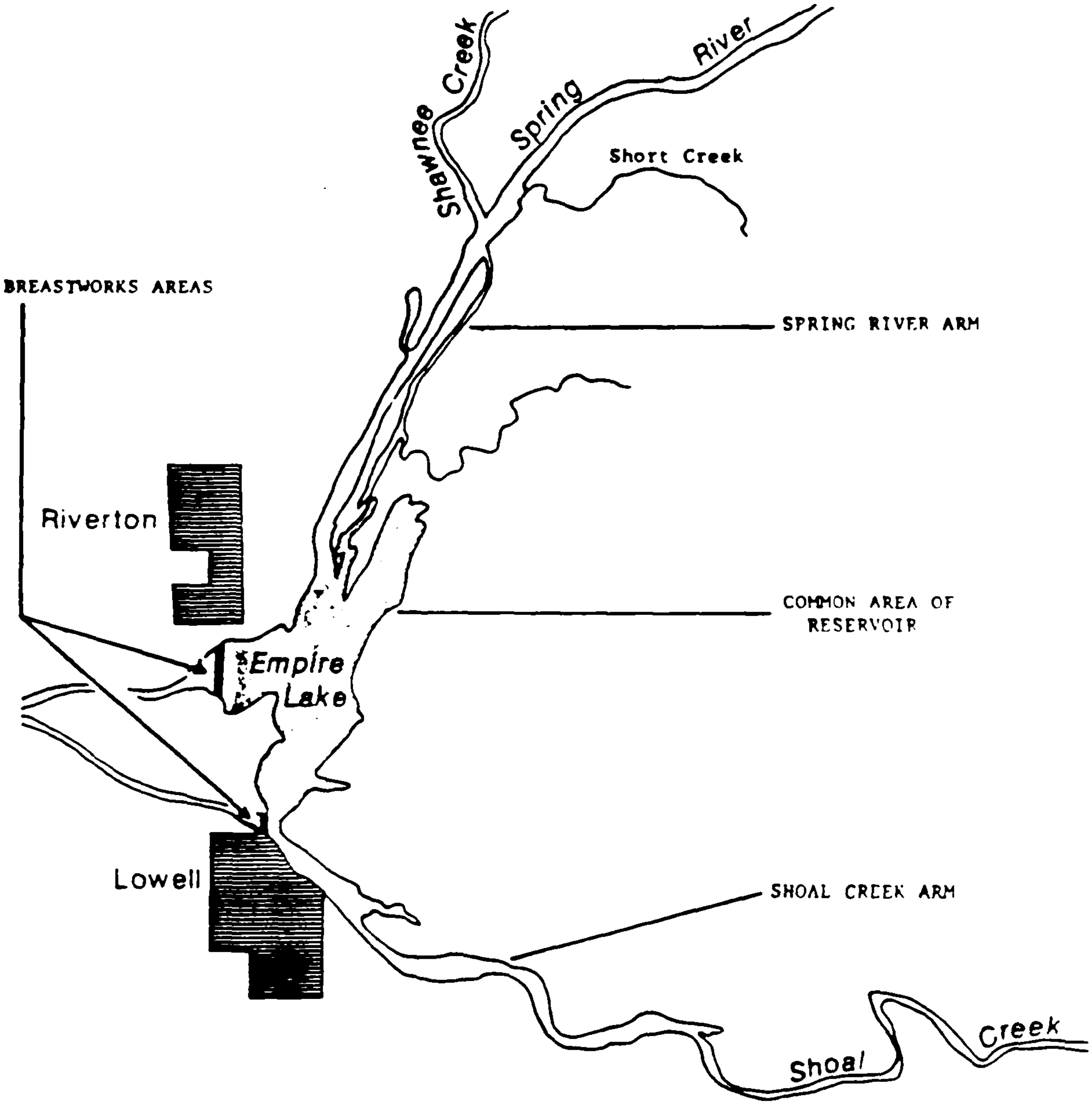

FIGURE 3: Empire Lake reservoir showing regions of reservoir referred to in text.

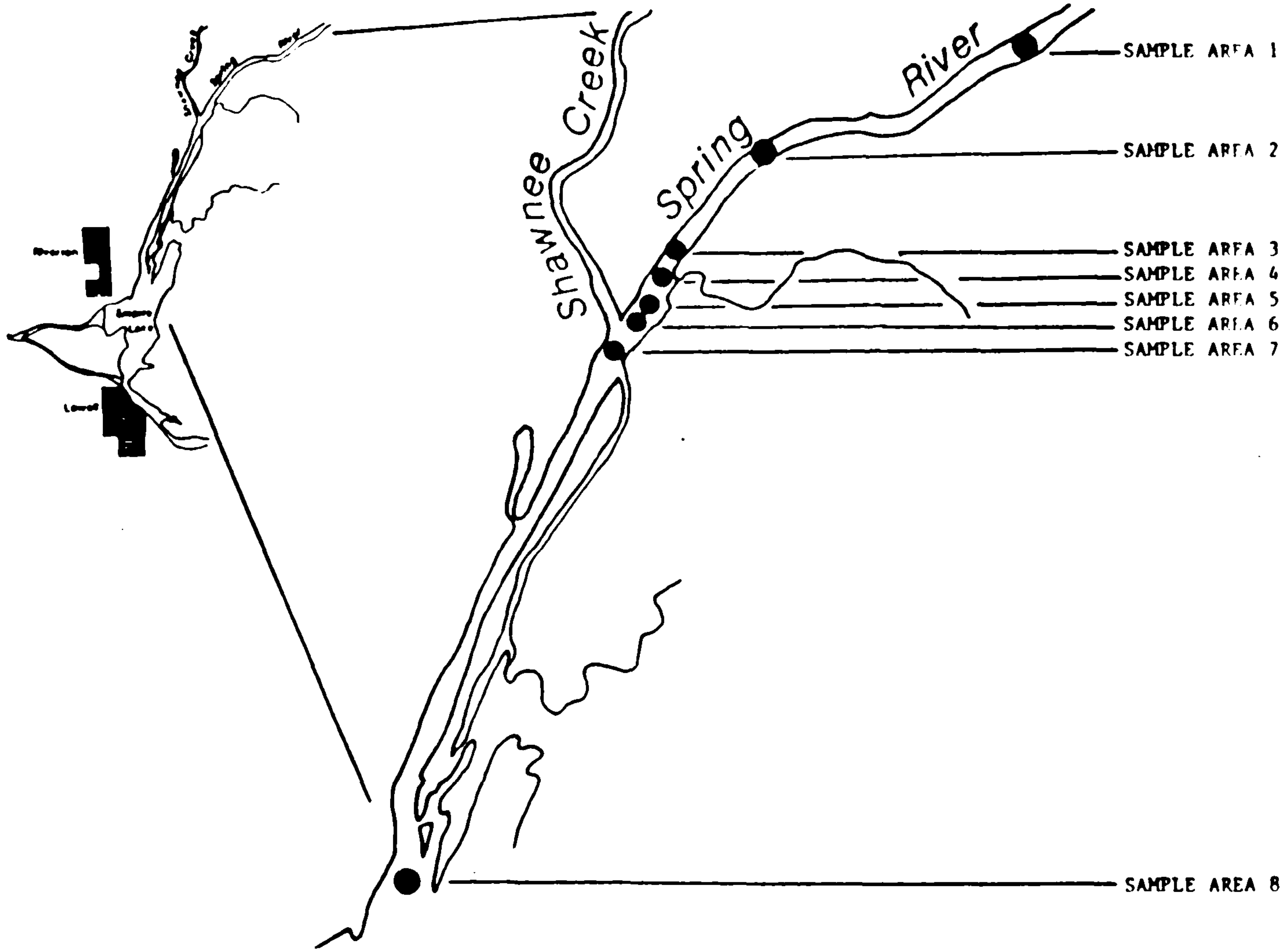

FIGURE 4: Map of Spring River arm of reservoir showing areas where temperature and oxygen profiles were taken. Profiles were taken at east bank, middle and west bank at each site.

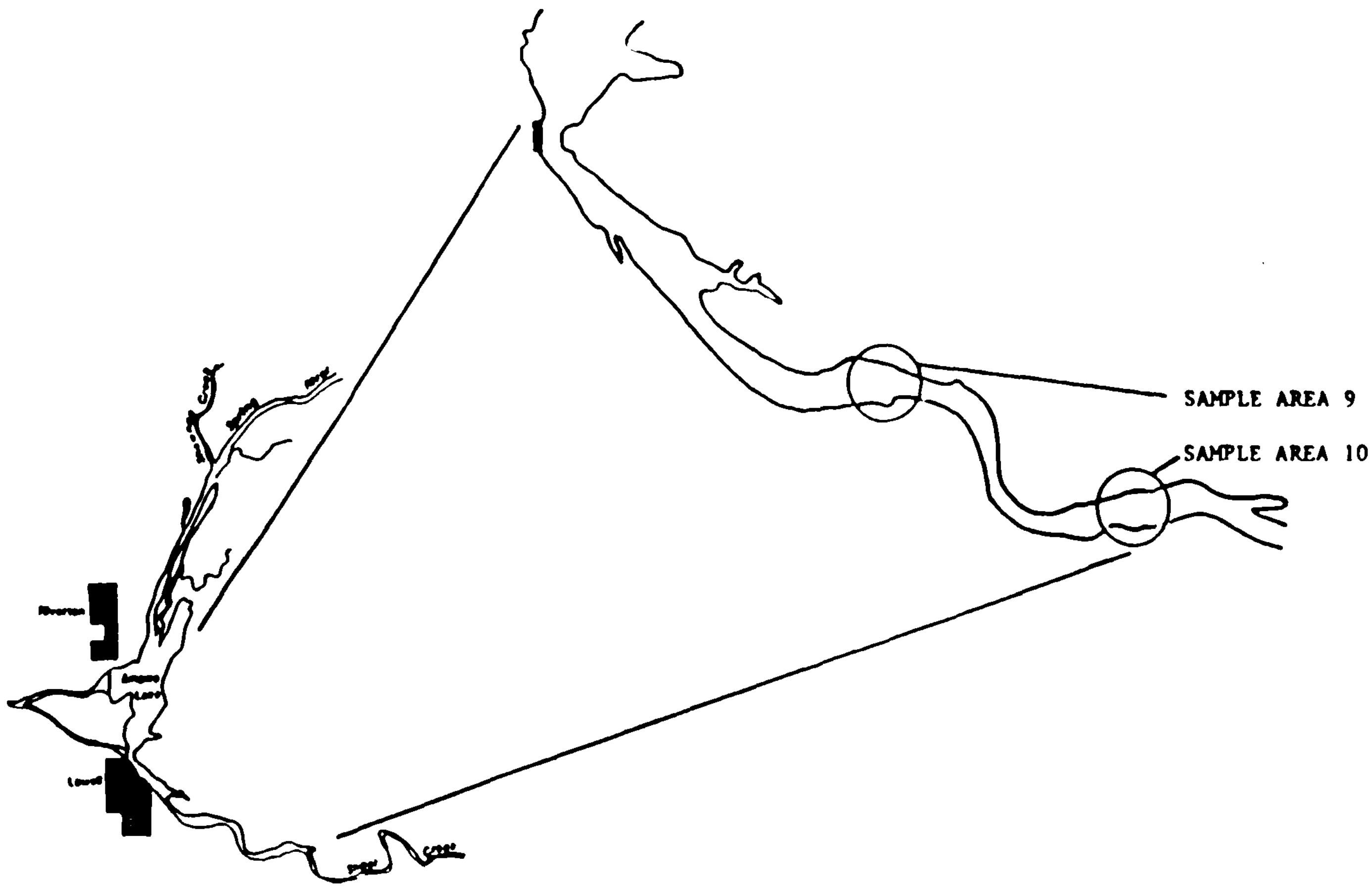

FIGURE 5: Map of Shoal Creek arm of reservoir showing areas where temperature and oxygen profiles were taken. Profiles were taken at north bank, middle and south bank at each site.

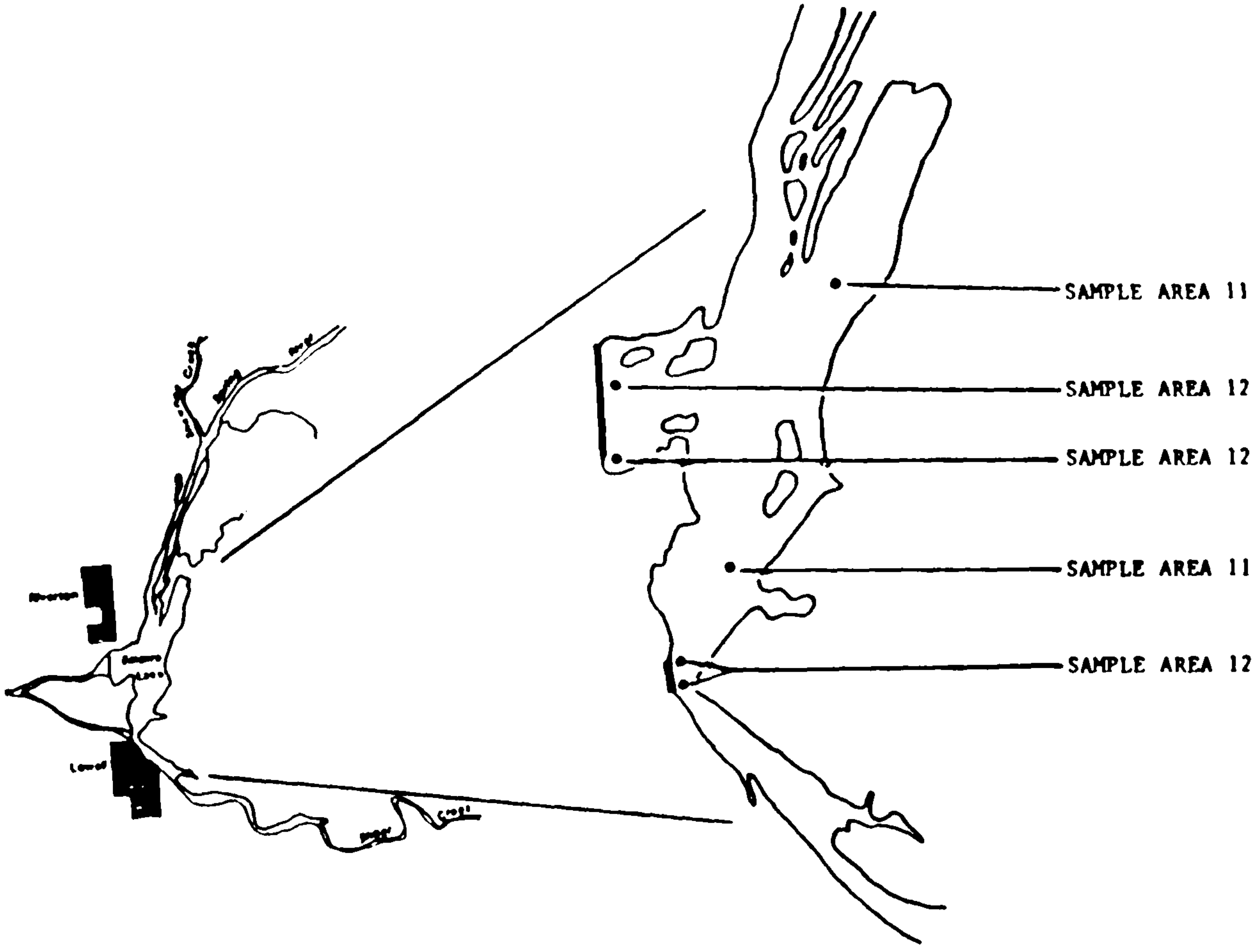

FIGURE 6: Map of common area and breastworks areas of reservoir where temperature and oxygen profiles were taken. One profile was was taken at each of the points indicated by dots.

three sampling points along a transect. The proposed transect sites are marked on figures 4 and 5.

An automatic chart-type depth recorder was used to determine the depths and bottom configuration at each of the proposed transect sites before sampling. At sample sites 1, 2 and 3 in the Spring River arm of the reservoir the bottom is U-shaped with sides that drop sharply. For instance at a distance 3 meters from the shore the water depth usually exceeded 2-3 meters. Maximum depths for these sites occurred near the center of the transect and were 6.1, 6.0 and 6.0 meters respectively. Beginning with transect 4 and extending through transect 7 it became obvious that the maximum depth near the center of the transect was much less than up-reservoir of this area. Maximum depths at these sites were less than five meters.

Upon attempting to sample this area it became clear that the decrease in depth was due to a large amount of gravel and/or chat that is accumulated in the arm at this point. There was no or only a small amount of fine sediment material accumulated on this coarse material and we could not effectively sample it with the Ekman dredge. In order to determine more precisely the extent of accumulated gravel and chat in this area a depth reading was taken in a north south direction starting at the railroad bridge up-reservoir of sample site 3 and proceeding along a course through the middle of the arm to a point down-reservoir of transect 7. A copy of this depth chart is included as figure 7.

The depth chart in figure 7 clearly indicates that there is a hill of gravel and chat that has accumulated near the confluence of Short Creek with the Spring River arm of the reservoir. This hill of gravel and chat is presumably derived, at least in part, from the erosion of materials from the

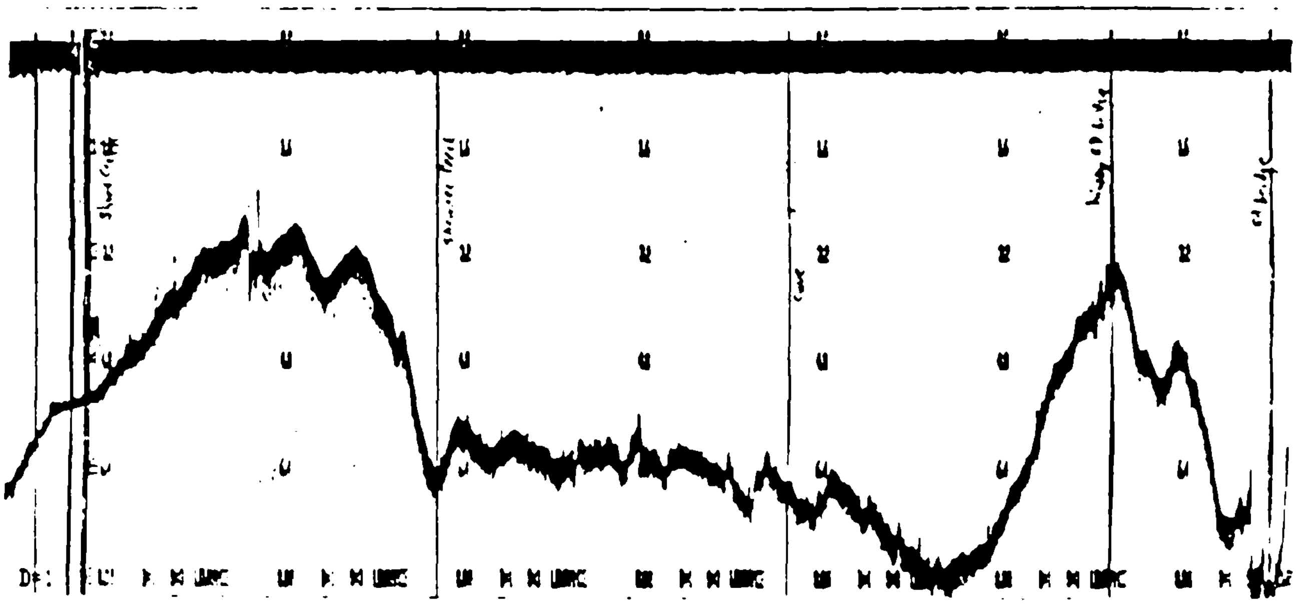

FIGURE 7: Depth chart of the Spring River arm in the vicinity of the confluence by Short Creek. North is to the left of the chart. The chart shows the depths along a transect through the center of the arm from the railroad bridge up-reservoir of sample site 3 to the railroad bridge near sample site 8. The hill of gravel and chat can be seen on the left.

mined areas of the upper part of the Short Creek watershed. There was only a small amount of fine sediment accumulated on this hill, and the texture of the more-coarse sediments precluded sampling near the center of transects 4-7. Figure 8 shows the alternative sample points that were selected based upon field-modification of the original design. Temperature and dissolved oxygen profiles were, however, taken according to the original design as shown in figure 4-6.

It was often necessary to sample rather close to shore because of the steep grade associated with the U-bottom configuration of the Spring River arm. The sections of bottom with steep grade were composed of clays and other rather consolidated material and lacked an accumulation of fine organic sediments.

The Spring River arm at sample site 8 begins to widen and the old stream bed is also much wider and less abruptly U-shaped. The maximum depth is again comparable to those recorded at transects 1 and 2, however the bottom at maximum depth has considerable gravel and also could not be sampled.

Sample sites 9 and 10 were located in the Shoal Creek arm of the reservoir. These two sites were originally conceived to be "control" sites where metal concentrations were expected to be low. This judgment was based upon the lack of perennially flowing streams out of mined areas and confluencing with the arm. Although there was mining activity in the watersheds to the north and east just up-reservoir of these sites it was felt that the rate of transfer of metals into the arm via surface water conduits would be low and that there would not be substantial accumulation of metals in the reservoir sediments.

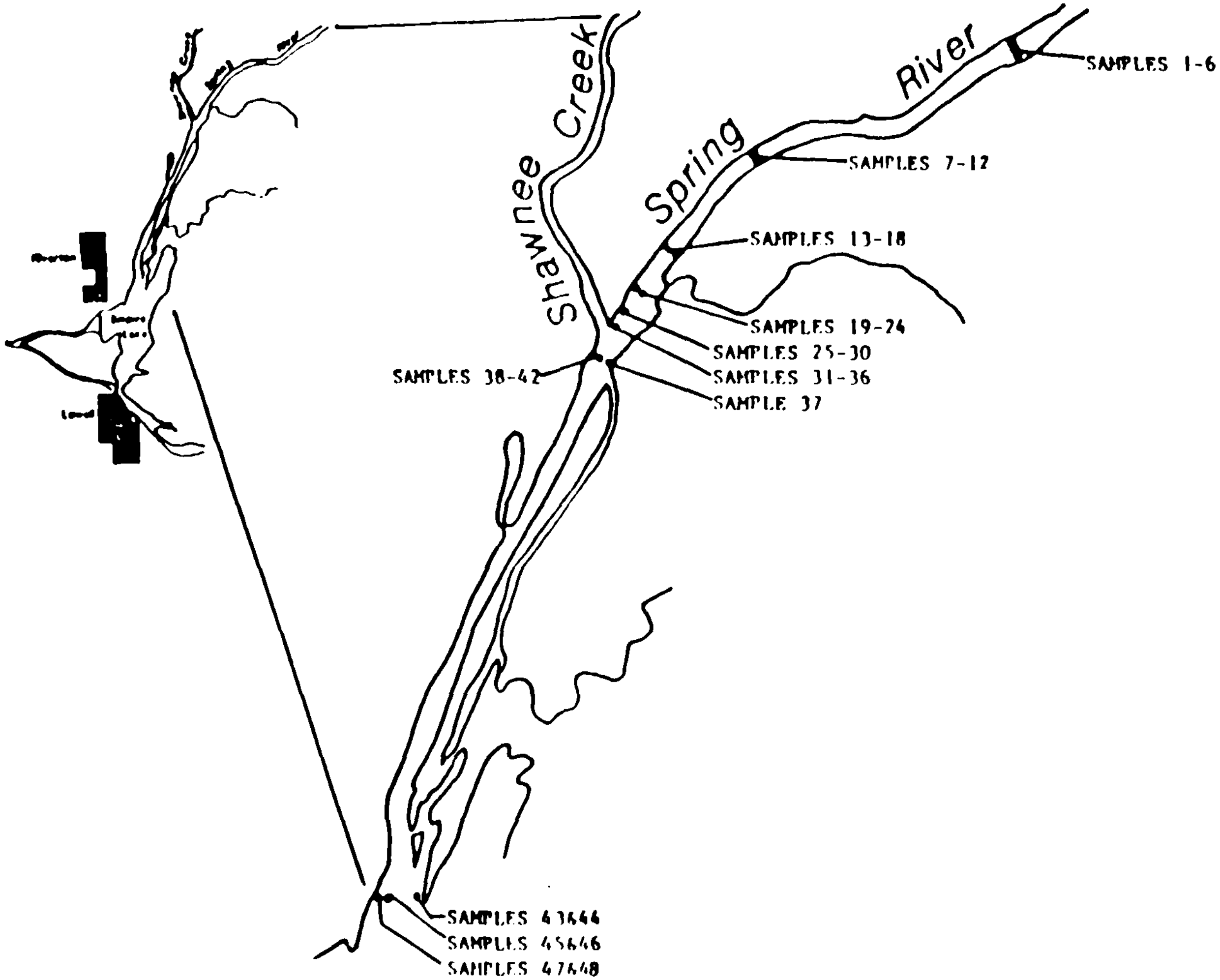

FIGURE 8: Locations of sediment samples taken in Spring River arm.

There were moderate amounts of fine sediments and clays present at sample site 9 and the samples were collected according to the original design. Only one sample could be collected from the center of sample site 10 because of gravel in the old river bed, otherwise sampling was completed according to design (see figure 10).

Sample site 11 was located in the common area of Empire Lake (see figure 9). This area consists of low-land areas between the two old river basins that were inundated by water as the reservoir filled. Most of this region is shallow, less than 1.5 meters deep, and has large accumulations of fine sediments and clays as substratum. Three replicate samples were taken at each of two points in this area.

Sample site 12 consisted of the areas in the vicinity of the two breastworks (see figure 9). It was expected that these two sites would have either the deepest depths or, alternatively, would have the most dense accumulations of fine sediments and clays, depending upon current patterns and sedimentation rates in the reservoir. In either case, it was expected that the conditions would be nearly identical or very similar at the two breastworks.

It was found after obtaining depth readings and sampling that the sediment characteristics and sedimentation conditions near the breastworks were very different. The region near the Riverton Dam is shallow by comparison to the corresponding region near the Lowell Dam. The maximum depth 30 feet from the Riverton Dam was 2 - 2.9 meters versus 4.6 - 4.8 meters at the corresponding point by the Lowell Dam. Substrate characteristics were quite different also. The predominant substrate at the Riverton Dam was coarse sand mixed with gravel and having only a thin covering of fine

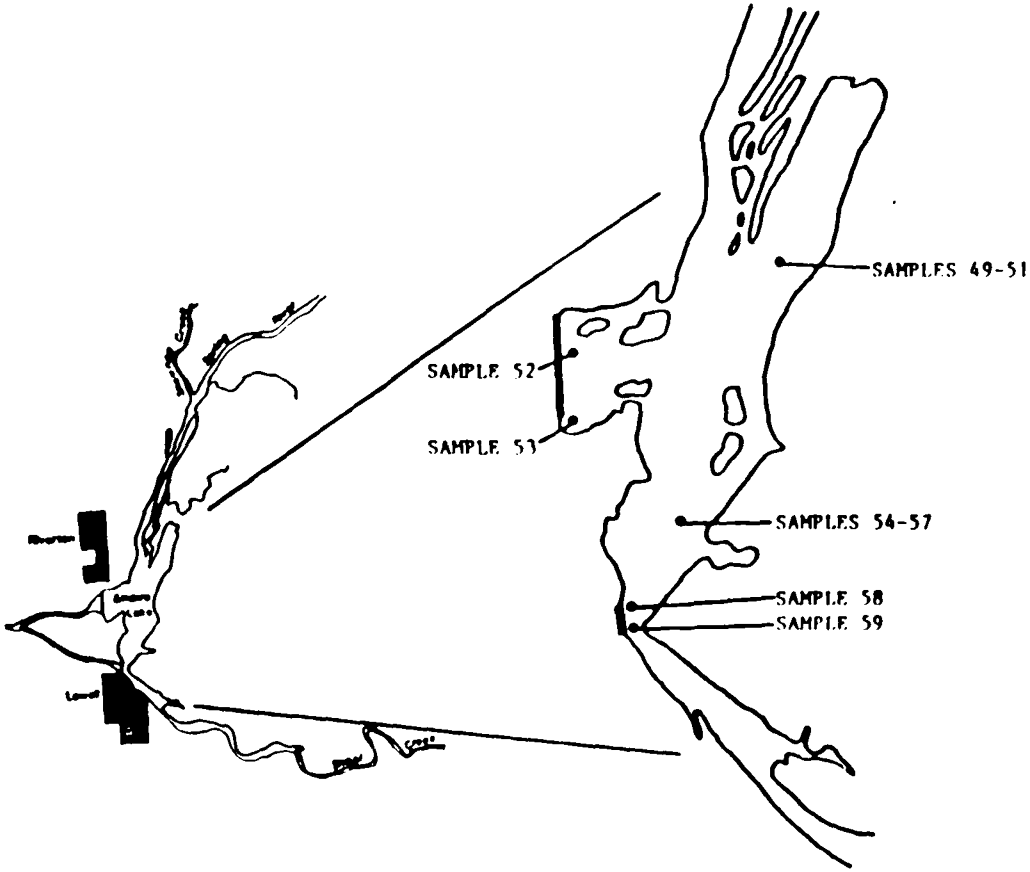

FIGURE 9: Location of sediment samples taken from the common area and breastworks areas of the reservoir.

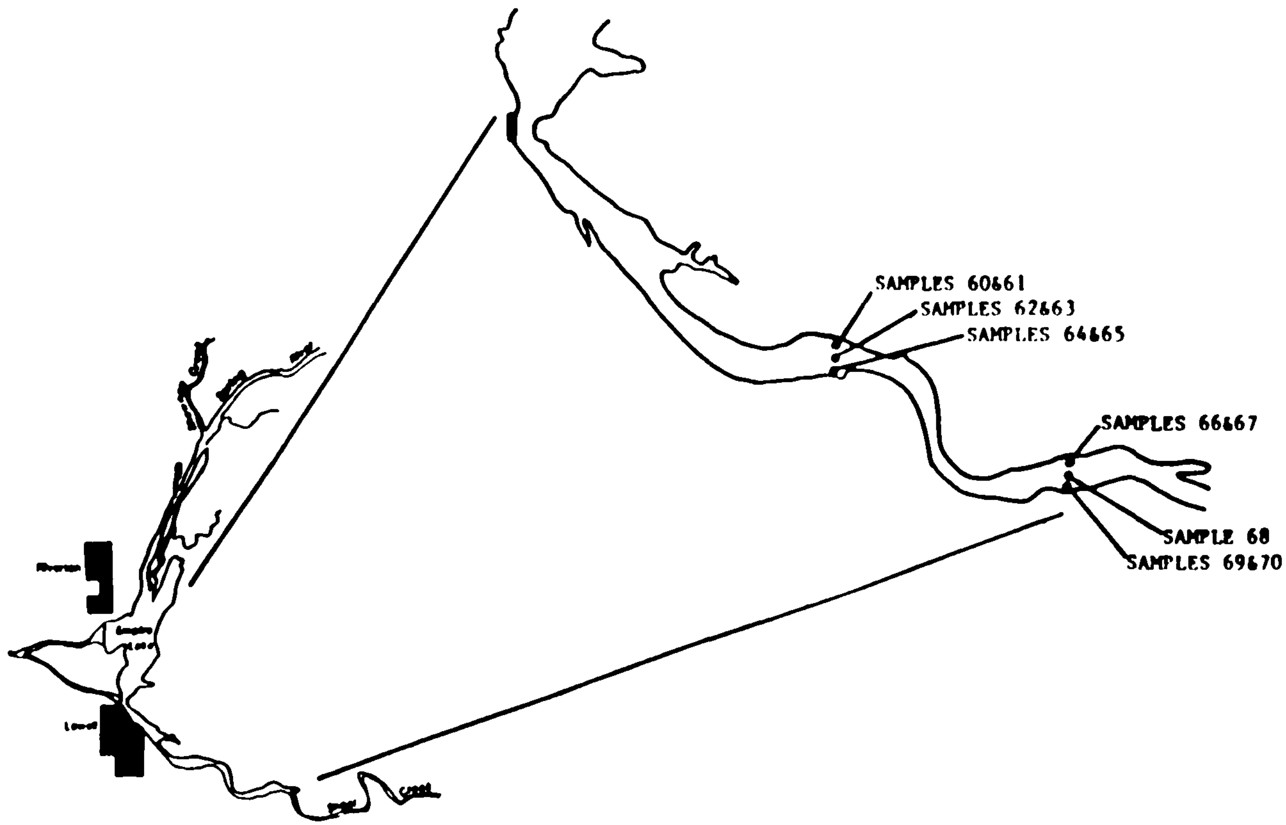

FIGURE 10: Location of sediment samples taken from the Shoal Creek arm of the reservoir.

sediments. In contrast the substrate at the Lowell Dam were predominantly fine sediments and clays.

Only one sample could be collected along the breastworks of Riverton Dam because of the sand and gravel substrates. The second sample was taken to the south of the breastworks in a shallower area where soft sediments have accumulated. Both samples at the Lowell Dam were taken according to our original design.

METHODS, MATERIALS AND PROCEDURES

Objective 1

Samples of Reservoir sediments were taken on 26-27 May 1987 and 15-16 September 1987. Seventy samples were collected on each date. This report summarizes the results for the seventy samples collected in May. Results of the September samples will be in our project completion report for next year.

Figures 8-10 show the number and position of sample sites. For purposes of replication and statistical analyses, each sample site was considered to represent a region of the reservoir and the samples collected from each site are considered to be replicates for the respective region. Samples in the up-reservoir reaches of the Spring River arm of the reservoir (sites 1 and 2) and in the Shoal Creek arm (sites 9 and 10) were expected to be low in concentrations for the metals to be analyzed, and were designated as prospective "control" sites. In order to give high resolution of the depositional patterns of sediments that are eroded from Short Creek, samples sites 3-7 were established in close proximity to the point of confluence with the Spring River arm. The remaining sample sites were established at selected locations in the reservoir where it was anticipated that the metals would be present, but in concentrations lower than near the point of confluence for Short Creek. All of these sites were viewed as impacted sites, however the magnitude of impact was expected to vary. By selecting sample sites throughout the reservoir we also felt that the design would enable us to develop a map of metal deposition within the reservoir.

Each sample was taken using an Ekman dredge sampler with a 15.2 x 15.2 cm opening. A small subsample of sediment was taken from the upper 2-3 cm of each sample. Sediment subsamples were stored in the field in a cooler with ice and were dried at 100 degrees C upon return to the lab. The samples were capped after drying and transferred to Karmie Galle at the Kansas Geological Survey (KGS) for analysis.

Sample Processing and Preparation

The field number of each sample was recorded when they were delivered to the KGS laboratories. Each sample was then assigned a laboratory number to insure proper identification as the analytical process was carried out.

The samples were ground, with a mortar and pestle, to a grain size sufficient to pass through an eighty mesh screen. Following this, the samples were thoroughly mixed to insure uniform homogeneity. Mixing was done by placing the sample on a sheet of cellophane and folding it into itself by rolling the sample back and forth numerous times. The sample was judged to be properly mixed when a uniform color was observed after it was smoothed and packed with a spatula.

Analytical Method

A one gram sample was weighed out and placed in a 100 ml glass beaker. Seventy five ml of 4 normal nitric acid was then added to the beaker. The beaker was then placed on a hot plate and the sample digested for twenty four hours at a temperature of approximately eighty degrees centigrade. While still warm, the samples were filtered into 100 ml volumetric flasks. The filter papers were washed with warm 4 normal nitric acid to make sure that all soluble material was removed from the filter and placed in the volumetric flasks. The flasks were then allowed to cool before being made up to volume. These were the stock solutions of acid soluble material which were analyzed for cadmium, lead, manganese and zinc.

Standard flame atomic absorption methods were employed in the analysis of these solutions. Numerous references can be cited which describe analytical atomic absorption. For a good description of various atomic absorption methods, the reader is referred to the book by Van Loon (1980). A more complete treatment of the theory, components and techniques of atomic absorption can be found in Dean and Rains (1969a, 1969b, 1975).

The lower limits of sensitivity for the elements determined in this study are as follows: lead, manganese and zinc -0.05 parts per million (ppm); cadmium -0.01 ppm. The concentration of manganese and zinc in these samples was such that a 50 times dilution of the stock solution was required to determine the correct concentration present. No dilution was necessary for the analysis of cadmium and lead. The standard practice in this KGS laboratory requires a reproducibility of two percent or less. For the concentration of the elements being determined in this study standard deviations of 1 or less and relative standard deviations of 5% or less can be expected.

The analyses were carried out on an Instrumentation Laboratories atomic absorption spectrometer, Model Video 22. The instrument is a two channel unit that has a built-in automatic background correction system. The instrument has an internal computer system which allows it to plot standard curves and a readout of the concentration of the element being analyzed.

Precision and accuracy is checked in several ways. Of primary concern in any atomic absorption analysis is the sample matrix. In all analyses carried out in this study, the matrix of the standard solutions was matched to that of the sample solutions. If the matrix of the sample solution and the standards is not carefully monitored the accuracy of the analyses cannot be guaranteed. In this laboratory, matrix effects are checked in one of two ways. The method of standard additions is commonly used to study matrix effects and determine if they are affecting the accuracy of an analysis. A description of the method of additions can be found in ASTM Standard Practice E 663 (1987). A second procedure used to study matrix effects is also used to monitor the performance of the atomic absorption instrument used in the analysis of the samples and involves the following. A known concentration of the element being determined is added to an aliquot of a sample solution. This sample is then analyzed and compared to the analysis of the same sample to which no addition has been made. If the comparison shows that all of the element added to the sample aliquot has been accounted for or recovered, it may be assumed that the instrument is performing correctly and the matrix effects are negligible. This second practice was employed in the analysis of these samples. Finally, a standard sample was analyzed along every set of samples analyzed during this study. A standard sample is one which has been analyzed by several different methods and the exact concentration of the various elements determined. The standard example used with this study was National Bureau of Standards sample #1646, an estuarine sediment. If the analysis of

Euparal as a mounting medium. All slides have been retained and incorporated into the museum-type collections of the Kansas Biological Survey (KBS) and are available for inspection.

Chironomidae larvae were slide mounted by first detaching the headcapsule from the body and then positioning the body laterally and the head ventral side up for easier identification. Chaoboridae larvae were mounted laterally and with several specimens to one slide because they are easier to identify and fewer genera were present in the study. Ceratopogonidae larvae were mounted ventral side up as is standard for their identification.

Identification labels were attached to all slides. Slide numbers were assigned at this time and marked on the labels along with state, county, landmark, transect, sample, date and collector information. Mounted and labeled slides were then placed in slide boxes and oven-dried at forty degrees Celsius for two weeks before identification.

Slide mounted larvae were then separated into groups of specimens that were alive when collected and those that were dead when collected. All live specimens were identified to lowest possible taxonomic level using Merritt and Cummins (1984) and a compound microscope. Identifications of the slide mounted specimens and other unmounted invertebrate specimens were recorded on standard lab data sheets. The data were collated for each sample and entered into a computer file for subsequent analyses.

Ecological measurements for the benthic invertebrates at each sample site were calculated using the ECOMEAS programs developed for KBS by Alex Slater (copyright 1986 by the KBS). This program runs on the microcomputers at the KBS and calculates 12 different measures of community diversity and 17 different measurements of community similarity. In addition, the program calculates the corresponding theoretical maximum and minimum values of the diversity index, two measures of evenness and the redundancy values of diversity indices for which these values can be derived. All of the values that were calculated are included in the appendix of this report.

A single set of diversity values was calculated for each sample site by summing the data of the 6 samples (4 samples in the case of sample site 12) and treating the summed values as a single "sample". For this approach the most appropriate index is Brillouin's (H) Index (Peilou, 1966). The index values, theoretical maximum and minimum values and the evenness values are summarized in tabular form in a subsequent section. For purposes of interpretation, higher values of (H) represent samples with higher information content and, presumably, "healthier" communities. Lower values are representative of communities that are experiencing higher degrees of pollution induced stress.

Brillouin's (H) Index uses both species richness (i.e. numbers of species present in a collection of samples) and the manner in which the specimens are distributed among the species categories to calculate diversity. Healthier communities are generally characterized by a larger number of species than stressed communities, and generally have a more uniform distribution of specimens among the species categories. Stressed communities are generally represented by one or a few species that are tolerant and consequently very abundant, and a larger group of less tolerant species that are only represented by a few specimens. Thus, the distribution of specimens across species categories is very skewed. The evenness value calculated from (H) is a measure of the distribution of specimens among species categories. Therefore, for any given value of (H), higher evenness values represent the standard sample appears to be incorrect, all samples analyzed in that particular set are analyzed again until the results of the analysis of the standard sample indicate a correct analysis.

Objective 2

Species richness, relative abundances and estimates of standing crop densities were determined for each of the sediment samples and averages were calculated for each of the sample sites. Only a small amount of the material collected from each Ekman Dredge sample was needed for the determination of the metal concentrations. The remainder of the sample was transferred to plastic containers in the field, 95% ethanol was added as a preservative, then the samples were placed in a cooler for transport back to the lab. Fresh preservative was added to the samples after returning them to the lab and they were stored in the plastic containers until sorted. Samples were carefully sorted in the lab to ensure that early instars and smaller species of macroinvertebrates were retained for identification and quantification. All specimens except for Diptera and Oligochaeta were identified to lowest possible taxonomic level using a dissecting microscope and counted.

Sediment samples were chosen at random from storage and searched for macroinvertebrates. A portion of each sample was diluted with tap water, stirred and poured into a light colored sorting tray to a depth shallow enough to allow visual detection of early instar chironomid larvae (a depth equal to the thickness of medium sized chironomid larvae). With each addition of diluted sediment the tray was tilted in a pattern (left, right, forward and back) to expose the invertebrates. The organisms were picked from the tray with forceps and placed in 95% ethanol in a vial and stored as separate samples until later identification. The excess diluted sediments were then decanted into three to five gallon sized plastic buckets. The process of stirring, pouring into the tray, searching and picking invertebrates, and decanting sorted sediments was repeated until a sample was completely searched through.

All sediment samples were processed by the same method. Samples collected in May were all sorted by one individual. Because of the greater volume of the September samples, three technicians processed these samples. The individual that sorted the spring samples assisted in and supervised the sorting of fall samples.

The buckets of diluted, sorted sediments were set aside after the completion of sorting for one to a few days to allow the suspended sediments to settle out of suspension. The water was then siphoned off and passed through filter paper using a vacuum pump at 15 pounds of pressure. The filter paper was air dried, labeled, and stored in plastic ziploc bags. The remaining wet sediments in the buckets were dried, transferred to smaller plastic containers and oven dried at 40 degrees C. Dried sediments were labeled and transferred to ziploc bags and stored with the filter paper. These will be used later in assessing sediment particle size classes of the sediment samples.

After all seventy samples from a given sampling effort were sorted into individual vials, all Chironomidae, Chaoboridae, and Ceratopogonidae larvae and Oligochaetes were permanently mounted on slides for identification. This was accomplished using a dissecting microscope by pouring all the specimens of one sample into a petri dish and hand picking the dipteran larvae and Oligochaetes into a separate dish containing fresh 95% ethanol. All specimens from each sample were mounted individually or in groups on slides using healthier communities and lower evenness values represent more stressed communities.

For purposes of determining standing crop biomass estimates some qualitative collections of macroinvertebrates were collected from Empire Lake and other habitats in Kansas. Selected specimens from each size class were chosen, lengths and headcapsule widths measured and then specimens were dried at 100 degree C until constant weights were attained. Weights were recorded for each size class for each species of macroinvertebrate that occurred in sufficient numbers in the samples, and length/weight regressions were developed. These regressions will enable us to estimate standing crop biomasses by measurement of length or headcapsule width, without having to destroy specimens by drying. Specimens that were not dried in order to develop the length/weight regressions were retained for future reference in the museum-type collections of the Kansas Biological Survey (KBS). Voucher collections have been made for both teaching and research purposes and are available upon request.

Objective 3

We attempted to develop Empirical models relating the concentrations of cadmium, lead, zinc and manganese to the species richness and standing crop densities of benthic taxa using multiple regression analysis.

The heavy metal concentrations in substrate samples were viewed as 4 independent variables and either species richness or standing crop densities as the dependent variables. Depth of water from which the samples were taken also influenced the number of taxa collected and the densities observed in the samples, and was used as a fifth independent variable.

NCSS procedures for Regression Analysis were employed and the analyses were run on microcomputers at KBS. The hierarchical importance of the four metals and depth was determined with regard to (1) species richness and (2) standing crop densities for the 70 samples collected for each of the two sample dates.

It was anticipated that the field design would result in samples with differing amounts of heavy metals and that the effects of metals would be to reduce species richness and productivity of benthic macroinvertebrates as metal levels increase. Insofar as standing crop densities usually are a reliable estimate of production, we anticipated using the density values to make inferences about potential effects of metals upon system-level production. By analyzing the loss of species as metal levels increase, it was assumed that we would be able to define the levels of metals that result in the extirpation of x-percent of the species relative to the control samples. Based upon these results recommendations regarding the target levels of metal concentrations in substrates that should not be exceeded in order to protect a given percentage of the resident benthic biota were to be formulated. The advantage of this empirical approach to setting criteria is that response modes of the resident community in its normal ambit and natural complexity are evaluated, rather than attempting to make predictions back to the community based upon artificial lab experiments that bear little resemblance to the complex conditions encountered in a field setting.

Objective 4

The recommendations that will be formulated from our research will be precisely stated and thoroughly discussed in our final report. They will, of course, depend upon the outcome of analysis of both May and September samples and require no additional comment at this time.

Objectives 5 and 6

The analyses of whole body burdens of cadmium, lead, zinc and manganese are not completed as of this writing. When finished they will provide us with insight into possible biomagnification of these metals. If there are accumulations of any of these metals, particularly cadmium or lead, in tissues of fishes then the possibility of human health hazards due to consumption of sport fishes will need to be considered.

DATA ANALYSIS

The raw data from the metals analyses and biological sampling was computerized with the help of a spreadsheet in the Number Cruncher Statistical System (NCSS) computer package. A print-out was made and the data was proofread, dated and signed. A sorting variable for depth was entered and stored. The depth categories were designated as follows: depths less than 1 meter were assigned a value of 1, depths equal to or greater than 1 meter but less than 2 meters were assigned a value of 2, depths equal to or greater than 2 meters but less than 3 were assigned a value of 3, depths equal to or greater than 3 meters but less than 4 meters were assigned a value of 4, depths equal to or greater than 4 meters but less than 5 meters were assigned a value of 5, depths equal to or greater than 5 meters but less than 6 meters were assigned a value of 6, depths equal to or greater than 6 meters and less than 7 meters were assigned a value of 7. There was only one sample from a depth greater than 6 meters and there were no depths greater than 7 meters in the reservoir.

All statistical analyses were accomplished with the NCSS computer package. Descriptive statistics, such as the mean, variance, 95% confidence limits around the mean, skewness (G_1), and the kurtosis (G_2), were calculated for each metal and for all benthic invertebrates based upon all seventy samples. These results were used to check the assumptions of Analysis of Variance (ANOVA) and regression analysis. An important assumption of all parametric tests is that the variables are normally distributed. Both G_1 and G_2 were checked for statistical significance against the t-distribution with infinite degrees of freedom using the formulae by Sokal and Rohlf (1981).

$$t = G_1 \quad 6/n \quad \text{and} \quad t = G_2 \quad 24/n$$

When the raw data were not normally distributed, transformations were tested using a special routine in NCSS until one was found that fit the assumptions. The transformed data were stored for use in subsequent analyses.

Data subsets used in ANOVA were also tested for homogeneity of variances using the F-max distribution described by Sokal and Rohlf. NCSS was used to sort the data into groups and to calculate the variance using the descriptive statistics routine. The F-max calculations were then done by hand. The goal was to use alpha = 5% for significance. In most cases, the transformations provided homogenous variances. Since the majority of the transformed data conformed well to the assumptions of parametric tests, it was decided that parametric rather than non-parametric tests would be justified.

RESULTS

Water Temperature and Oxygen Profiles

Water temperature and oxygen profiles versus depth are given in Tables 1 and 2. Depths from which samples were taken varied from less than one meter to 6.1 meters. Water temperatures varied from 24.2 degrees C to 20.3 degrees C during the May sample period. There was no indication of thermal stratification and development of a thermocline at any of the sample stations. Water temperatures gradually decreased with depth, but were never more than 3.2 degrees C lower than the surface water temperature.

Oxygen concentrations were also highest at the surface and decreased only slightly with depth. Oxygen was always detected and with only one exception was always greater than 4.6 mg/liter at a point .25 meters from the sediment surface, thus there was no indication of oxygen depletion at any of the sample sites. The average oxygen concentration at the surface of the water was 7.26 mg/liter. The average concentration at 0.25 meters above the sediments was 5.82 mg/liter.

Oxygen concentrations were highest at sample site 11, which was located in the common area of Empire lake. Concentrations at the surface were 9.3 mg/liter and 8.4 mg/liter. Surface concentrations at sample sites in the Shoal Creek arm were second highest, averaging 8.66 mg/liter at sample site 10, 8.4 mg/liter at Lowell Dam and 7.76 mg/liter at sample site 9. Surface water concentrations of Oxygen varied between 6.2 mg/liter and 7.2 mg/liter at all other sample sites except the east bank locations at sample sites 4 and 5, where they were 8.4 mg/liter and 7.8 mg/liter, respectively. These two sample

TABLE 1: Water temperatures (degrees Centigrade) by depth at each sample site. Three readings were taken for each sample site in the Spring River and Shoal Creek arms of the reservoir. Two readings were taken at each breastworks and one reading was taken at each of two sites within the common area of Empire Lake. Maximum depth is indicated in parenthesis to the right of the reading at 0.25 meters from the bottom.

	Sample Site 1			Sample Site 2		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	21.5	21.9	22.0	23.8	22.2	21.9
1 meter	21.0	21.2	21.5	--	21.8	21.2
2 meters	21.0	21.1	--	--	21.0	21.0
3 meters	21.0	21.0	--	--	20.9	20.9
4 meters	20.9	21.0	--	--	20.9	20.9
5 meters	20.9	21.0	--	--	--	20.9
6 meters	--	21.0	--	--	--	--
.25 meters from bottom	20.9(5.3m)	21.0(6.1m)	21.5(1.5m)	22.2(0.6m)	20.9(6.0m)	20.8(5.0m)

	Sample Site 3			Sample Site 4		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	22.0	23.1	22.9	24.2	22.2	22.0
1 meter	21.9	22.0	22.8	22.0	22.0	22.0
2 meters	21.7	21.8	--	21.0	21.1	--
3 meters	--	21.1	--	21.0	--	--
4 meters	--	21.0	--	21.0	--	--
5 meters	--	21.0	--	21.0	--	--
6 meters	--	--	--	--	--	--
.25 meters from bottom	21.2(3.0m)	21.0(6.0m)	21.4(2.0m)	21.0(5.2m)	21.0(3.0m)	21.8(2.0m)

Table 1, continued Water temperature by depth.

	Sample Site 5			Sample Site 6		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	22.0	22.0	22.0	22.0	22.0	22.0
1 meter	21.8	21.9	21.9	21.9	21.9	22.3
2 meters	--	21.2	21.1	--	21.2	--
3 meters	--	21.0	21.0	--	21.0	--
4 meters	--	21.0	--	--	21.0	--
5 meters	--	--	--	--	--	--
6 meters	--	--	--	--	--	--
.25 meters from bottom	21.8(1.4m)	21.0(4.3m)	21.0(3.4m)	21.9(1.3m)	21.0(4.3m)	22.3(1.1m)

	Sample Site 7			Sample Site 8		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	22.1	22.2	22.5	23.0	22.7	23.3
1 meter	--	22.0	21.3	22.8	22.4	--
2 meters	--	21.5	--	--	22.4	--
3 meters	--	21.3	--	--	22.2	--
4 meters	--	21.1	--	--	21.1	--
5 meters	--	--	--	--	21.1	--
6 meters	--	--	--	--	21.0	--
.25 meters from bottom	22.0(0.6m)	21.0(4.9m)	21.3(1.0m)	22.8(1.0m)	21.0(6.0m)	23.1(0.5m)

	Sample Site 9			Sample Site 10		
	North Bank	Middle	South Bank	North Bank	Middle	South Bank
Surface	23.0	23.2	23.2	22.1	22.2	22.3
1 meter	20.9	21.8	--	21.9	22.0	22.1
2 meters	--	21.5	--	--	21.9	--
3 meters	--	--	--	--	--	--
4 meters	--	--	--	--	--	--
5 meters	--	--	--	--	--	--
6 meters	--	--	--	--	--	--
.25 meters from bottom	20.6(1.5m)	21.2(2.5m)	22.1(0.3m)		21.9(1.4m)	21.9(2.4m)
22.1(1.1m)						

Table 1, continued Water temperature by depth.

	Sample Site 11	
	Northern Site	Southern Site
Surface	24.1	23.0
1 meter	23.9	22.8
2 meters	--	--
3 meters	--	--
4 meters	--	--
5 meters	--	--
6 meters	--	--
.25 meters from bottom	23.9(1.1m)	22.3(1.4m)

	Sample Site 12			
	Riverton Dam North Site	Riverton Dam South Site	Lowell Dam North Site	Lowell Dam South Site
Surface	23.9	22.0	23.0	23.0
1 meter	23.1	--	22.5	22.5
2 meters	22.0	--	22.0	22.4
3 meters	--	--	22.0	21.8
4 meters	--	--	21.2	21.4
5 meters	--	--	--	--
6 meters	--	--	--	--
.25 meters from bottom	22.0(2.0m)	21.6(0.7m)	20.3(4.8m)	20.8(4.6m)

TABLE 2. Oxygen concentrations (in mg/liter) by depth at each sample site. Three readings were taken for each sample site in the Spring River and Shoal Creek arms of the reservoir. Two readings were taken at each breastworks and one reading was taken at each of two sites within the common area of Empire Lake. Maximum depth is indicated in parentheses to the right of the reading at 0.25 meters from the bottom.

	Sample Site 1			Sample Site 2		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	6.4	6.4	6.3	7.7	6.4	6.4
1 meter	6.4	6.1	6.1	--	6.3	6.3
2 meters	6.0	5.9	--	--	6.1	6.0
3 meters	5.9	5.9	--	--	6.0	6.0
4 meters	6.0	5.8	--	--	5.9	5.9
5 meters	6.0	5.8	--	--	5.9	--
6 meters	--	5.6	--	--	5.6	--
.25 meters from bottom	5.2(5.3m)	5.6(6.1m)	5.8(1.5m)	6.1(0.6m)	5.6(6.0m)	5.6(5.0m)
	Sample Site 3			**Sample Site 4**		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	6.4	6.7	6.8	6.4	6.5	6.5
1 meter	6.3	6.4	6.7	6.5	6.3	6.2
2 meters	5.7	6.0	--	5.6	5.8	--
3 meters	--	5.7	--	5.4	--	--
4 meters	--	5.5	--	5.4	--	--
5 meters	--	5.5	--	5.3	--	--
6 meters	--	--	--	--	--	--
.25 meters from bottom	4.8(3.0m)	5.5(6.0m)	5.5(2.0m)	5.2(5.2m)	5.6(3.0m)	4.7(2.0m)
	Sample Site 5			**Sample Site 6**		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	7.8	6.3	6.4	7.1	6.9	6.8
1 meter	7.0	6.3	6.2	6.8	6.3	4.8
2 meters	--	5.6	5.5	--	5.8	--
3 meters	--	5.6	5.5	--	5.6	--
4 meters	--	5.4	--	--	5.5	--
5 meters	--	--	--	--	--	--
6 meters	--	--	--	--	--	--
.25 meters from bottom	6.9(1.4m)	5.0(4.3m)	4.8(3.4m)	6.4(1.3m)	5.2(4.3m)	4.8(1.1m)

Table 2, continued Oxygen concentrations by depth.

	Sample Site 7			Sample Site 8		
	East Bank	Middle	West Bank	East Bank	Middle	West Bank
Surface	8.2	6.8	7.0	6.9	6.8	7.2
1 meter	--	6.2	5.8	6.7	6.8	--
2 meters	--	6.1	--	--	6.6	--
3 meters	--	5.5	--	--	6.6	--
4 meters	--	5.3	--	--	5.4	--
5 meters	--	--	--	--	5.2	--
6 meters	--	--	--	--	3.9	--
.25 meters from bottom	5.3(0.6m)	4.8(4.9m)	5.8(1.0m)	6.7(1.0m)	3.9(6.0m)	6.6(0.5m)

	Sample Site 9			Sample Site 10		
	North Bank	Middle	South Bank	North Bank	Middle	South Bank
Surface	7.8	7.6	7.9	8.6	8.7	8.7
1 meter	7.2	7.3	--	8.2	8.2	8.2
2 meters	--	6.9	--	--	7.5	--
3 meters	--	--	--	--	--	--
4 meters	--	--	--	--	--	--
5 meters	--	--	--	--	--	--
6 meters	--	--	--	--	--	--
.25 meters from bottom	6.6(1.5m)	5.9(2.5m)	7.0(0.3m)	6.9(1.4m)	5.1(2.4m)	8.3(1.1m)

	Sample Site 11	
	Northern Site	Southern Site
Surface	9.3	8.4
1 meter	8.8	8.4
2 meters	--	--
3 meters	--	--
4 meters	--	--
5 meters	--	--
6 meters	--	--
.25 meters from bottom	8.8(1.1m)	6.4(1.4m)

Table 2, continued Oxygen concentrations by depth.

	Sample Site 12			
	Riverton Dam North Site	Riverton Dam South Site	Lowell Dam North Site	Lowell Dam South Site
Surface	7.4	6.9	8.5	8.3
1 meter	8.8	--	8.2	8.3
2 meters	--	--	8.0	8.0
3 meters	--	--	8.1	8.0
4 meters	--	--	7.0	7.3
5 meters	--	--	--	--
6 meters	--	--	--	--
.25 meters from bottom	5.6(2.0m)	6.0(0.7m)	5.8(4.8m)	5.9(4.6m)

sites are just down reservoir of the confluence by Short Creek and the high oxygen concentrations at the east bank locations show the influence of the highly aerated stream water as it enters the reservoir.

Metals Concentrations in Sediments

Analysis of sediments has shown that concentrations of cadmium, lead, manganese and zinc are elevated throughout all areas sampled in the reservoir. Cadmium concentrations ranged from undetectable (in one sample) to 49.8 parts per million (ppm), with 80% of the May samples having 10 or more ppm. Lead concentrations ranged from 9.28 ppm to 341.5 ppm, with 83% of the May samples having 100 or more ppm. Manganese concentrations ranged from 293.7 ppm to 1370 ppm in the May samples, with 76% of the samples having 500 or more ppm. Zinc concentrations ranged from 100 ppm to 5,503 ppm in the May samples, with 94% of the samples having 1000 or more ppm. Data for the metal concentrations in the

September samples are not fully worked-up at this writing, but indicate that the September concentrations are approximately equal to or slightly in excess of the values determined for the May samples.

The average cadmium concentrations and the corresponding 95% confidence interval estimates by sample site are given in Table 3. The highest average concentrations of cadmium occurred in sample area 11, which is the shallow water common area of Empire Lake. The mean concentration of 41.04 ppm at this site was significantly different (p>.05) from the mean concentration found at any of the other sample sites.

TABLE 3. Concentrations of Cadmium by sample site in Empire Lake based upon May samples. All values given as ppm. Means followed by the same letter are not significantly different from each other based upon ANOVA and Newman/Keul's Range Test (p= .05).

Sample Site	Mean Concentration	95% Confidence Interval	Median Concentration	Range of Concentrations
1	7.89a	4.19-12.76	9.92	0.00-10.30
2	8.97ab	8.43- 9.52	8.91	8.44- 9.56
3	12.43abc	4.13-25.20	10.45	2.23-27.20
4	16.65abcd	10.37-24.41	16.18	8.10-28.80
5	13.74abc	10.53-17.37	13.07	10.50-19.40
6	20.20 cd	13.24-28.61	21.60	12.10-30.00
7	20.53 cd	11.15-32.75	23.86	8.97-34.30
8	17.76 b d	15.42-20.25	16.90	15.50-20.90
9	21.55 cd	17.46-26.08	20.90	17.90-26.60
10	26.87 d	21.34-33.04	28.70	17.00-31.90
11	41.04	32.84-50.14	41.10	33.30-49.80
12	23.19 cd	12.55-37.09	25.20	13.50-30.80

The mean concentrations of cadmium at sample sites 1-5 were not significantly different from each other (p = .05). All of these sample sites were located in the Spring River arm of the reservoir. With the exception of the mean for sample site 1, the mean concentrations were also not significantly different from the mean concentration of cadmium at sample site 8. Site 8 was located at the point where the Spring River arm begins to open up into the common area of the reservoir, and is down-reservoir from the point where Short Creek confluences with the Spring River arm. These six sample sites in the Spring River arm exhibited the lowest concentrations of cadmium.

Sample sites 3-7 were located nearest to the point of confluence by Short Creek. Mean cadmium values for these five sites were not significantly different from sample site 8, also in the Spring River arm, and sample sites 9 and 12. Sample sites 9 and 12 were located in the Shoal Creek arm and at the breastworks of the Riverton and Lowell Dams, respectively. These sites are characterized by intermediate concentrations of cadmium, as is sample site 10, which is also located in the Shoal Creek arm. The cadmium concentration at sample site 10 was not significantly different from the above group of sample sites, with the exception of sample site 3, which had the lowest average concentration of cadmium of this group of sample sites and was located just up-reservoir of the confluence by Short Creek.

The concentrations of lead in sediments are given by sample site in table 4. The highest average concentrations of lead occurred at sample sites 7, 9, 10, 11 and 12. The means for these five sites did not significantly differ from each other (p = .05). The sites are located in the Shoal Creek arm of the reservoir, at the breastworks of the two dams, in the common area of Empire Lake and down-reservoir of the confluences of Short Creek and Shawnee Creek.

The mean values for lead at sample sites 2, 3, 4, 6, 7 and 8 were each not significantly different from each other, and also from the above group, with the exception of sample site 11, located in the common area of Empire Lake. This second group of sample sites were located in the Spring River arm of the reservoir and occurred both up-reservoir and down-reservoir of the confluence of Short Creek.

The mean concentrations of lead at all sample sites in the Spring River arm, with the exception of sample site 5, are all not significantly different from each other. They are significantly lower in average concentration of lead than sample sites 9, 10 and 11. The average concentrations of lead at sample sites 1-6 and sample site 8 also do not significantly differ from each other, and had the lowest concentrations of lead.

The concentrations of manganese in the reservoir sediments are given by sample site in table 5. The highest average concentrations of manganese occurred at sample sites 2-5, 7 and 11 and 12. The means for these sample sites did not differ significantly from each other ($p = .05$). With the exception of sample sites 4 and 2 which exhibited the two highest average concentrations of all the sample sites, the means of manganese concentrations at sample sites 1, 6 and 8 also did not differ significantly from the above group of sample site means.

Sample sites 9 and 10, located in the Shoal Creek arm of the reservoir exhibited the lowest mean concentrations of manganese. The means for these two sample sites did not differ significantly from each other, but were significantly lower than the means of all the other sample sites.

TABLE 4. Concentrations of Lead by sample site in Empire Lake based upon May samples. All values given as ppm. Means followed by the same letter are not significantly different from each other based upon ANOVA and Newman/Keul's Range Test (p= .05).

Sample Site	Mean Concentration	95% Confidence Interval	Median Concentration	Range of Concentrations
1	84.66ab	37.94-149.89	118.35	16.70-122.30
2	109.20abc	91.62-128.32	111.50	88.20-134.10
3	149.18abc	61.68-274.70	125.48	36.70-292.50
4	119.54abc	83.43-162.10	120.49	62.90-171.20
5	66.86a	18.21-146.07	103.57	9.28-127.40
6	130.37abc	87.46-181.82	136.84	83.00-202.30
7	197.77 bcd	82.48-362.67	245.02	62.80-340.20
8	115.97abc	99.16-134.07	109.45	101.30-138.40
9	207.56 cd	168.27-251.00	216.27	165.20-245.10
10	239.20 cd	200.14-281.77	247.28	169.80-274.50
11	291.04 d	249.10-336.24	288.76	246.50-341.50
12	175.75 bcd	78.91-310.85	179.40	109.80-248.40

TABLE 5. Concentrations of Manganese by sample site in Empire Lake based upon May samples. All values given as ppm. Means followed by the same letter are not significantly different from each other based upon ANOVA and Newman/Keul's Range Test (p= .05).

Sample Site	Mean Concentration	95% Confidence Interval	Median Concentration	Range of Concentrations
1	604.62 b	442.76-791.63	664.40	320.0-718.0
2	958.26 cd	640.59-1339.71	922.15	657.0-1360.0
3	890.96 bcd	739.73-1056.32	859.49	737.0-1196.0
4	996.29 d	739.57-1291.25	972.82	816.5-1370.0
5	876.22 bcd	730.73-1034.91	846.81	756.2-1164.0
6	626.35 bc	486.20-784.19	672.73	444.7-776.7
7	694.01 bcd	506.16-911.50	691.85	491.1-913.7
8	600.94 b	539.82-665.28	617.12	497.6-659.0
9	328.01a	302.06-354.98	324.86	293.7-369.2
10	376.71a	350.51-403.89	363.59	357.8-418.6
11	738.43 bcd	498.63-1025.15	729.43	509.2-1013.2
12	708.30 bcd	373.22-1149.89	610.63	559.7-1114.0

The concentrations of zinc in the reservoir sediments are given by sample site in Table 6. The highest average concentrations of zinc in the reservoir occurred at sample sites 10, 11 and 12, which are the up-reservoir sample site in Shoal Creek, the sample site in the common area of Empire Lake, and the sample site at the breastworks, respectively. The mean concentrations of zinc at these sites did not differ significantly (p = .05).

TABLE 6. Concentrations of Zinc by sample site in Empire Lake based upon May samples. All values given as ppm. Means followed by the same letter are not significantly different from each other based upon ANOVA and Newman/Keul's Range Test (p= .05).

Sample Site	Mean Concentration	95% Confidence Interval	Median Concentration	Range of Concentrations
1	948a	340-1860	1304	100-1619
2	1353ab	1246-1464	1348	1211-1493
3	1723abc	704-3190	1530	425-3338
4	1642abc	919-2572	1698	803-3088
5	1555abc	1354-1770	1518	1365-1946
6	2134 bcd	1608-2734	2226	1545-2751
7	2748 cde	1598-4210	2984	1316-4442
8	2728 cde	2320-3168	2545	2406-3425
9	2842 cde	2494-3214	2918	2360-3319
10	3862 ef	3312-4454	3977	2920-4389
11	4554 f	3620-5595	4520	3723-5503
12	3147 def	1522-5355	3438	1697-4346

The mean concentrations of zinc at sample sites 7, 8 and 9, which are the down-reservoir sample sites in the Spring River (7 & 8) and Shoal Creek arms of the reservoir did not differ significantly from the mean concentrations at sample sites 10 and 12, but did differ significantly from the mean of sample site 11, which had the highest mean concentration of zinc of all the sites investigated.

Sample sites 1-5 in the Spring River arm of the reservoir had the lowest mean concentrations of zinc. With the exception of sample site 1, which had the lowest mean concentration of all sites investigated, the mean values of the sample sites in close proximity to the confluence by Short Creek (sites 2-6) all had similar concentrations of zinc.

Analyses of variance was conducted to determine if there were differences in the concentrations of the four metals by depth. As indicated in the Data Analysis section, depth categories were defined and seven depth categories were used in this ANOVA. Results of ANOVA indicated that there is no added component of variance due to depth for cadmium, lead and zinc. Manganese has a highly significant added component of variance due to depth ($p>.0001$). The mean values of manganese versus depth increased with depth up to 6 meters, reaching average concentrations of 1327 ppm at depths of 5-6 meters. Cadmium, lead and zinc concentrations showed no relationship to depth.

Product moment correlation coefficients were calculated for all combinations of the metals two at a time. Cadmium, lead and zinc are highly positively correlated. Manganese shows a weak negative correlation with cadmium.

Species Richness, Relative Abundance and Estimates of Standing Crop Densities of Aquatic Macroinvertebrates

The aquatic macroinvertebrates in sediment samples collected from Empire Lake in May are listed in table 7. Thirty eight taxa were collected, representing the aquatic insect orders Ephemeroptera, Megaloptera, Odonata and Diptera. In addition several species of Oligochaeta were collected but could not be identified to lower taxonomic levels.

Aquatic Diptera were the most species rich and the most abundant group of macroinvertebrates, representing 84.2% of the taxa collected and 76.5% of the specimens. Chironomidae was the dominant family of Aquatic Diptera. The Chironomidae represented 71% of total taxa and 68.5% of total specimens.

Oligochaeta was the second most abundant taxon, representing 14.4% of macroinvertebrate specimens collected. The burrowing mayflies of the genus Hexagenia (Ephemeridae) were the third most abundant taxon, representing 8.2% of total specimens collected.

The tribe Chironomini was the most species rich group of Chironomidae with 13 taxa. Tanypodinae was second most species rich with 10 taxa present, followed by Tanytarsini and Orthocladiinae with 3 and 1 taxa present, respectively.

Tanypodinae were most common in the reservoir and represented 66.2% of the Chironomidae collected. Chironomini were second most common, representing 32.3% of the Chironomidae collected. Tanytarsini and Orthocladiinae were uncommon in the reservoir, representing 1.2% and 0.3% of the Chironomidae collected, respectively.

TABLE 7. Aquatic macroinvertebrates collected in 70 samples and corresponding % composition.

	Total Specimens Collected			Percent Composition		
Ephemeroptera	98			8.4		
Caenidae		3			0.2	
Caenis sp.			3			0.2
Ephemeridae		95			8.2	
Hexagenia sp.			95			8.2
Megaloptera	4			0.3		
Sialidae		4			0.3	
Sialis sp.			4			0.3
Odonata	3			0.2		
Gomphidae		2			0.2	
Gomphus sp.			2			0.2
Macromiidae		1			0.1	
Macromia sp.			1			0.1
Diptera	890			76.5		
Chaoboridae		51			4.4	
Chaoborus sp.			51			4.4
Chironomidae		797			68.5	
Ablabesmyia annulata			31			2.7
Ablabesmyia sp.			3			0.2
Coelotanypus sp.			18			1.5
Clinotanypus sp.			5			0.4
Labrundinia sp.			3			0.2
Procladius (*Holotanypus*) *sublettei*			364			31.3
Procladius (*Psilotanypus*) *bellus*			15			1.3
Tanypus sp.			12			1.0
Tanypus sp. 2			75			6.4
Telopelopia okoboji			1			0.1
Cladotanytarsus sp.			3			0.2
Paratanytarsus sp.			2			0.2
Tanytarsus sp.			5			0.4
Epoicocladius sp.			3			0.2
Chironomini genus "B"			3			0.2
Chironomus sp.			93			8.0
Cladopelma sp.			3			0.2
Cryptochironomus sp.			58			5.0
Cryptotendipes sp.			5			0.4
Dicrotendipes sp.			2			0.2
Glyptotendipes sp.			6			0.5
Harnischia sp.			13			1.1
Microchironomus sp.			17			1.5
Paralauterborniella nigrohalteralis			3			0.2
Polypedilum sp. 1			44			3.8
Polypedilum sp. 2			1			0.1
Tribelos sp.			9			0.8
Ceratopogonidae		41			3.5	

Table 7, Continued

Ceratopogonidae sp. 1		3		0.2
Ceratopogonidae sp. 2		19		1.6
Ceratopogonidae sp. 3		19		1.6
Unidentified Muscoid Diptera		1		0.1
Oligochaeta	182		14.4	

Procladius (Holotanypus) sublettei was the most widespread and abundant Chironomidae species in Empire Lake. This species represented 31.3% of the macroinvertebrates collected, and was present in 60 of the 70 samples taken in May. Chironomus sp., Tanypus sp. 2, Cryptochironomus sp. and Polypedilum sp. 1 were also common in the reservoir, representing 8.0%, 6.4%, 5.0% and 3.8% of the macroinvertebrates collected.

Chaoborus sp. (Diptera: Chaoboridae) was the only other aquatic macroinvertebrate that was moderately abundant in collections from Empire Lake. Fifty-one specimens, representing 4.4% of the aquatic macroinvertebrates were collected in May.

Standing crop densities based upon all 70 samples collected in May were calculated for species with a cumulative frequency of 1.3% or more. The density estimates by sample site are given in table 8.

Based upon preliminary scanning of the species richness and density data it was observed that there was a distinct trend with regard to depth from which the sample was collected. The biological data were then sorted by the same depth categories as for the metals and data were analyzed to determine the trend of species richness and standing crop densities. Table 9 presents these data and table 10 shows the densities of individual insect taxa at each depth.

TABLE 8. Standing crop densities by sample site for common taxa that comprize 1.3% of the total specimens collected in May. Density units are individuals/sq. meter.

Sample Site	1	2	3	4	5	6
Hexagenia sp.	72.1	28.8	21.6	36.1	7.4	79.3
Chaoborus sp.	--	50.5	28.8	50.5	14.4	21.6
Ablabesmyia annulata	21.6	7.2	14.4	64.9	14.4	7.2
Coelotanypus sp.	7.2	--	--	--	--	--
Procladius (*Holotanypus*) *sublettei*	93.8	158.7	223.6	295.7	274.1	180.3
Procaldius (*Psilotanypus*) *bellus*	14.4	7.2	28.8	7.2	--	--
Tanypus sp. 2	--	--	--	21.6	7.2	--
Chironomus sp.	28.8	36.1	50.5	64.9	158.7	14.4
Cryptochironomus sp.	72.1	14.4	50.5	14.4	7.2	36.1
Microchironomus sp.	14.4	21.6	21.6	7.2	14.4	7.2
Polypedilum sp. 1	21.6	7.2	--	--	--	21.6
Ceratopogonidae sp. 2	50.5	7.2	--	28.8	7.2	21.6
Ceratopogonidae sp. 3	21.6	--	--	7.2	--	21.6

Sample Site	7	8	9	10	11	12
Hexagenia sp.	93.8	14.4	57.7	209.2	36.1	28.8
Chaoborus sp.	137.0	--	--	--	28.8	36.1
Ablabesmyia annulata	28.8	--	--	43.3	--	21.6
Coelotanypus sp.	--	--	64.9	--	43.3	14.4
Procladius (*Holotanypus*) *sublettei*	202.0	72.1	14.4	173.1	872.8	64.9
Procaldius (*Psilotanypus*) *bellus*	28.8	7.2	--	14.4	--	--
Tanypus sp. 2	--	--	--	--	476.08	36.1
Chironomus sp.	122.6	43.3	--	28.8	101.0	21.6
Cryptochironomus sp.	50.5	101.0	--	43.3	7.2	21.6
Microchironomus sp.	28.8	7.2	--	--	--	--
Polypedilum sp. 1	14.4	28.8	21.6	21.6	151.5	28.8
Ceratopogonidae sp. 2	--	--	--	21.6	--	--
Ceratopogonidae sp. 3	14.4	7.2	21.6	36.1	7.2	--

TABLE 9. Distribution of species and standing crop densities with regard to depth in Empire Lake, May samples.

Depth Category	Number of Samples	Species Richness	Mean Number Per Sq Meter	95% Confidence Internal
1	14	21	349	238-473
2	25	30	822	426-1255
3	13	22	529	303-768
4	7	17	612	349-779
5	6	14	605	215-790
6	4	8	357	184-511
7	1	3	173	not calculated

There is a distinct depth effect for both species richness and standing crop densities. The pattern is fairly consistent with both richness and density having maximum values in depth class 2 (i.e. depth equal to or greater than one meter but less than two meters). Both richness and density were lower in the shallower waters, and species richness declined in a progressive fashion at depth classes greater than 2. The lowest value of three species for depth category was observed for category 7 (i.e. sample collected from depth exceeding 6.0 meters).

TABLE 10. Standing crop densities of aquatic insects versus depth category for May samples collected in Empire Lake.

Taxon	Depth Category						
	1	2	3	4	5	6	7
Hexagenia sp.	27.8	84.8	73.2	37.1	64.9	--	--
Ablabesmyia annulata	6.2	13.8	43.28	18.5	28.9	10.8	--
Ablabesmyia sp.	6.2	--	3.3	--	--	--	--
Coelotanypus sp.	6.2	12.1	23.3	--	14.4	--	--
Clinotanypus sp	3.1	6.9	--	--	--	--	--
Procladius (*Holotanypus*) *sublettei*	95.8	325.5	169.8	179.3	295.7	238.0	86.6
Procladius (*Psilotanypus*) *bellus*	3.1	12.1	3.3	24.7	--	10.8	43.2
Cladotanytarsus sp.	3.1	3.5	--	--	--	--	--
Chironomini genus "B"	6.2	1.7	--	--	--	--	--
Chironomus sp.	52.4	51.9	33.3	117.5	43.3	32.46	--
Cryptochironomus sp.	68.0	39.8	33.3	12.4	7.2	--	--
Dicrotendipes. sp.	6.2	--	--	--	--	--	--
Glyptotendipes sp.	15.4	--	3.3	--	--	--	--
Harnischia sp.	6.2	1.7	10.0	18.5	7.2	--	43.2
Microchironomus sp.	3.1	3.5	16.7	30.9	28.9	--	--
Paralauterborniella nigrohalteralis	3.1	--	3.3	6.2	--	--	--
Polypedilum sp. 1	21.6	50.2	10.0	6.2	21.6	--	--
Polypedilum sp. 2	3.1	--	--	--	--	--	--
Tribelos sp.	6.2	8.6	6.7	--	--	--	--
Ceratopogonidae sp.3	3.1	15.6	23.3	6.2	--	--	--
Chaoborus sp.	3.1	19.0	26.6	123.6	28.9	32.5	--
Caenis sp.	--	5.2	--	--	--	--	--
Sialis sp.	--	1.7	3.3	--	7.2	10.8	--
Gomphus sp.	--	3.5	--	--	--	--	--
Macromia sp.	--	1.7	--	--	--	--	--
Labrundinia sp.	--	5.2	--	--	--	--	--
Tanypus sp. 1	--	17.3	--	--	7.2	10.8	--
Tanypus sp. 2	--	114.2	6.7	6.2	36.0	10.8	--
Paratanytarsus sp.	--	1.7	--	6.2	--	--	--
Tanytarsus sp.	--	5.2	3.3	6.2	--	--	--
Epoicocladius sp.	--	1.7	6.7	--	--	--	--
Cladopelma sp.	--	3.5	--	6.2	--	--	--
Cryptotendipes sp.	--	8.6	--	--	--	--	--
Ceratopogonidae sp. 1	--	3.5	--	6.2	--	--	--
Ceratopogonidae sp. 2	--	17.3	23.3	--	14.4	--	--
Telopelopia okoboji	--	--	3.3	--	--	--	--

Mean standing crop densities did not decrease in a consistent fashion at intermediate depths. For instance the estimates of density for depth categories 4 and 5, which were 612 individuals/sq. meter and 605 individuals/sq. meter, exceeded the estimate of 529 individuals/sq. meter at depth category 3. All three of these estimates were, however, less than the estimates for depth category 2 and exceeded the density estimate for depth category 1. The mean number of individuals/sq. meter dropped off in a progressive manner at depth categories 6 and 7, reaching a minimum of 173 individuals/sq. meter at the deepest site.

Procladius (Holotanypus) sublettei was the only aquatic insect species that was present and abundant at all sample depths. Ablabemyia annulata, Chironomus sp. and Chaoborus sp. were present at all depth categories but category 7. Procladius (Psilotanypus) bellus was present at all depths but category 5 and Harnischia sp. was also present at all depths except one, depth category 6. Hexagenia sp., Cryptochronomus sp., Microchironomus sp. and Polypedilum sp. 1 all had similar distributions with regard to depth, being present at all depths except categories 6 and 7. Fifteen taxa were restricted to depths equal to or less than 3 meters.

Table 11 summarizes the Brillouin's (H) Index values for aquatic insects by sample site. Also included are the theoretical maximum and minimum values, V evenness values and the species richness. Sample site 1 in the Spring River arm of the reservoir exhibited the highest species richness with 22 taxa present. Sample site 10, which is the corresponding up-reservoir sample site in the Shoal Creek arm of the reservoir had the second highest species richness with 21 taxa present. Intermediate richness values of 17, 16 and 15 were obtained for sample sites 2 and 4, sample sites 5 and 6 and sample site 7, respectively. The lowest values were observed at sample site 3, just up-reservoir of the confluence by Short Creek, where 11 taxa were detected, and at sample site 9 in the down-reservoir site of the Shoal Creek arm where 9 species were detected. A total of 12 or 13 taxa were detected at the remaining sample sites.

A similar pattern is seen for species diversity. Calculated values ranged from a high of 2.246 NATS observed at sample site 1, to a low of 1.312 NATS at sample site 5. Sample site 10 exhibited the second highest value of 2.036 NATS. Four sample sites had (H) values less than 1.600 NATS. Product moment correlation coefficients were calculated for the (H) values and the corresponding mean values of cadmium, lead, manganese or zinc, however none of them were significant at $p=0.5$.

Regression Analyses

Linear regression analyses were performed in order to check for significant linear effects of metals concentrations on either species richness or standing crop densities. A separate simple regression analysis was performed for each metal using the individual concentrations as derived from each of the 70 samples as the independent variable and the corresponding values of richness or total insect density of the sample as the dependent variables. All tests were not significant at $p=.05$.

TABLE 11. Summary of community diversity values by sample site for Empire Lake based upon May samples. Values are derived from Brillouin's (H) Index and are in NATS (log base e).

Sample Site	(H)	Maximum Value	Minimum Value	V Evenness	Species Richness
1	2.246	2.647	1.239	0.715	22
2	1.854	2.378	1.016	0.615	17
3	1.512	2.054	0.582	0.632	11
4	1.790	2.490	0.724	0.604	17
5	1.312	2.345	0.734	0.359	16
6	1.780	2.357	0.896	0.605	16
7	1.953	2.411	0.565	0.752	15
8	1.679	2.107	0.915	0.641	13
9	1.572	1.758	0.721	0.821	9
10	2.036	2.677	0.863	0.646	21
11	1.510	2.384	0.237	0.593	13
12	1.877	2.016	0.907	0.875	12

Since we had already examined the relationship that depth of sample had upon species richness and standing crop densities, we ran a second set of simple linear regression analyses to test for linear relationships among depth categories. Depth was used as the independent variable and either richness or density was considered to be the independent variable. All eight of these regression analyses were not significant at p=0.5.

A final set of regression analyses were performed by first sorting the data by depth category then performing a regression for the effects of each of the metals upon richness or density within each depth category except category 7. As in previous regression analyses, the metal concentrations were considered to be the independent variable and either richness or density as the corresponding dependent variables. A total of 48 simple linear regression analyses were performed (six depth categories X four metals X two dependent variables).

Seven of the 24 regressions for metal concentrations versus LOG_{10} (density) were significant (p=.05). The regression results for cadmium, lead and zinc were very similar, as would be expected based upon their high degree of collinearity (see results of correlation analyses for metals presented in earlier section). All three metals showed negative influences upon standing crop densities of aquatic insects at the depth categories 1 and positive influences at depth 2. The intercepts, slopes, probability levels, and simple R-squared values are given in Table 12 for these two depth categories.

Manganese concentrations showed a positive relationship to density at depth category 3, but all other regressions produced non-significant results. The intercept, slope, probability levels and simple R-squared values are also given in Table 12.

Only four of the 24 regressions for metals concentrations versus species richness were significant (p=.05). Again the results for Cadmium, Lead, and Zinc were very similar, due to their collinearity. The intercepts, slopes, probability levels and simple R-squared values for the four significant regressions are given in Table 13.

Cadmium, lead and zinc concentrations all showed negative effects on species richness at depth category 1. The strongest relationship was seen for cadmium where the simple R-squared was 0.379 and the slope was -1.120. Manganese concentrations showed a weak, but significant, positive effect upon species richness at depth category 3.

TABLE 12. Results of simple linear regression analyses that showed statistical significance for the effect of metal concentration in sediments on standing crop density within a depth category. Density data were transformed using LOG_{10} (density) before analysis in order to satisfy normality and homocedasticity assumptions.

Independent Variable	Depth Category	Intercept	Slope	Probability Level	Simple R-squared
Cadmium	1	1.228	-0.018	0.024	0.357
Cadmium	2	0.789	0.016	0.002	0.360
Lead	1	1.186	-0.002	0.010	0.435
Lead	2	0.698	0.002	0.002	0.349
Zinc	1	1.248	-0.590	0.027	0.348
Zinc	2	0.751	0.001	0.002	0.352
Manganese	3	0.538	0.007	0.035	0.346

TABLE 13. Results of simple linear regression analyses that showed statistical significance for the effects of metal concentrations in sediments on species richness within a depth category.

Independent Variable	Depth Category	Intercept	Slope	Probability Level	Simple R-squared
Cadmium	1	9.041	-1.120	0.019	0.379
Lead	1	8.178	-0.330	0.030	0.336
Zinc	1	9.216	-0.095	0.021	0.371
Manganese	3	-3.334	0.344	0.039	0.333

DISCUSSION AND CONCLUSIONS

The goal of this study was to evaluate the occurrence and biological effects of cadmium, lead, manganese and zinc in sediments of Empire Lake. In order to achieve this goal a series of six objectives were defined. The data presented in this report relate to objectives 1-3. Research continues with regard to objectives 4, 5 and 6 and the results will be presented in a subsequent report.

Before discussing the results that relate to objective 1, a few comments are in order with regard to the initial design of this study. Previous to our study there were no detailed evaluations of the sediment characteristics, oxygen and temperature profiles, depths and/or macroinvertebrates of Empire Lake available to us for review. Therefore in designing the field study we made a series of assumptions about the occurrences of cadmium, lead, zinc and manganese in the reservoir and of their potential effects on benthic macroinvertebrates. Our assumptions about metals concentrations and sediment characteristics were based upon some results of preliminary investigation by the U.S. EPA (Anonymous 1984, 1985), by the KDHE (Anonymous 1980) and the U.S.G.S. (Spruills, 1984). Our assumptions about benthic responses were based upon limited data regarding macroinvertebrate responses to heavy metal pollution in other geographic areas, but by necessity the assumptions were formulated with little regard to the comparability of the site characteristic of these other habitats to those of Empire Lake, and include studies of both lentic (Forstner and Prosi, 1979; Havas and Hutchinson, 1982; Kraft and Sypniewski, 1981; Wickham et al., 1987) and lotic habitats (Brown, 1977; Burrows and Whitton, 1983; Clarke, 1974; LaPoint et al., 1984; Warren, 1981; Winner et al., 1980).

It became obvious to us early in this study that many of our assumptions were not very accurate and that the original field design would have to be slightly altered in order to accomplish the study. We modified the field collecting in a manner that was, to the best of our professional judgment, most compatible to the intent of the original design. In this section of the report we will address the situations when original assumptions were not born-out, and will offer justification for field-modifications of the sampling design. As is often the case when original assumptions prove to be inaccurate, it is because of a lack of literature and solid data foundation upon which to build, rather than because of basic conceptual flaws. We feel that the data which we have generated will well serve the needs of subsequent investigations, while at the same time satisfying our original objectives. And again, as if often the case, we find that we have a better concept of the distribution and occurrence of heavy metals in Empire Lake and the way in which the macroinvertebrates respond to these metals in sediments, albeit at the expense of the accuracy of several *a priori* assumptions.

Depths, Temperature Profiles and Oxygen Profiles

In order to be able to infer cause and affect relationships between the metals of interest and the responses by aquatic macroinvertebrates it is first necessary to evaluate other physical and habitat parameters that are known to affect them and then to sequentially rule them out or hold them constant while assessing the parameters of interest, in this case the concentrations of cadmium, lead, zinc and manganese in sediments. Since depth and oxygen concentrations can influence macroinvertebrate richness and standing crop densities we first determined these conditions within the reservoir.

Sampling at different depths has revealed that there is a significant effect upon patterns of species richness and standing crop density (Harper and Cloutier, 1986; Brinkhurst, 1974; Sublette, 1957). In this study we attempted to sample at sites that exhibited a range of depths in order to separate the effects of depth from the effects of metals concentration. In Empire Lake the maximum depth that we encountered was slightly in excess of 6.1 meters. For purposes of analysis, we defined depth categories based upon 1.0 meter intervals, and took multiple samples from each category except the maximum depth category 7, where we only obtained one sample.

Temperature and Oxygen can have a profound effect upon benthic macroinvertebrates especially if thermal stratification of the water column occurs in lentic systems during summer months. It was our concern that if temperature stratification occurs in Empire Lake then this would cause depletion of oxygen in the hypolimnion which would reduce the species richness and standing crop densities of macroinvertebrates in deeper regions of the reservoir irrespective of metals concentrations in the sediments.

The results of our temperature and oxygen profiles indicate that there was no thermal stratification nor substantial hypolimnetic depletion of dissolved oxygen on either of the two dates sampled (May and September). We did not calculate residence time of the water in the reservoir, but it would seem to us that residence time is low and it is unlikely that the arms of the reservoir become stratified. The shallow depth of the common area of Empire Lake also precludes thermal stratification in this portion of the reservoir.

Sediment Characteristics

We based our field sampling design upon a report by EPA which indicated that there were fine silt and non-consolidated clays sediments in the reservoir. Since heavy metals in solution are known to bind to fine silts and clays we felt that an analysis of the organisms living in these types of sediments would best reveal cause and effect relationships because they are surrounded by the metals and they have the greatest probability for cuticular absorption of the metals, for inadvertent consumption of sediment particles with high metals concentrations and for consumption of prey items that have high body burdens of metals and/or large amounts of metals adhering to their integument. We therefore attempted to restrict our field sampling efforts to soft sediments and intentionally excluded shallow areas that had extensive accumulations of coarse detritus or sand, gravel and cobble.

It was not possible to sift the sediment samples into size fractions as part of this study, however the sediments of all 140 samples were saved and will be analyzed during the up-coming year. Data for sediment characteristics will be incorporated into refined models that will be subsequently developed.

The sediment characteristics of Empire Lake are more heterogeneous than originally anticipated. In the up-reservoir areas of the Spring River arm (sample sites 1-3) the reservoir is U-bottomed, with the sides sharply dropping to a depth of about 6.0 meters. The sides are generally compacted clays or other consolidated material and have very little accumulation of fine sediments. Consequently the samples that were collected in shallow water zones near the banks of the Spring River arm were usually taken a distance of 2 meters or less from the shore.

At sample site 1 there was some fine sediment over coarse gravel in the center of the arm and only one sample as taken here in May. There was a large amount of fine sediment at sample site 2, both along the banks and in the center. This accumulation of fine sediment was the result of the "hill" of gravel and chat which occurs down-reservoir of this site, which we presume acts to trap fine sediments in the deeper sections up-reservoir of it.

Sample sites 3-7 occurred near the confluence of Short Creek with the Spring River arm of the reservoir. A total of 30 sediment samples were scheduled to be taken from this relatively small area of the reservoir in order to provide us with high resolution of the depositional patterns of the metals that enter the arm from Short Creek. Spruill (1984) calculated that 673 pounds per day of zinc and 4.57 pounds per day of cadmium are transported in the lower reaches of Short Creek, and that most or all of this load ends up in Empire Lake. A high percentage of the metal load in the stream water is in solution or tied up to suspended particulate solids. Differences in pH and buffering capacity of water in Empire Lake relative to Short Creek are likely to result in precipitation of the metals in solution as the water from Short Creek mixes with the reservoir water. Empire Lake is also very turbid and the suspended solids load is high, therefore we expected that most of the non-precipitated metals would become rapidly bound to the suspended solids and would either eventually settle-out of the water column or be transported through out the reservoir. We therefore predicted that we would observe a sharp increase in the concentration of the metals of interest in the vicinity of sample sites 4-7, but would observe decreasing concentrations down-reservoir at sample sites 8, 11 and 12.

Our depth readings in the area of sample sites 3-7 showed that there is a large hill of material accumulated in the Spring River arm near the confluence by Short Creek and just up-reservoir of the confluence by Shawnee Creek. Dredge sampling from this area confirmed the presence of the hill and indicated that it was composed of fine gravel and chat material. The Ekman Dredge does not perform well in this type of sediment so no quantitative sediment samples could be taken. Since it was our intention to restrict our sampling to fine organic sediments and clays we adjusted our original field design and obtained most of our samples from sample sites 4-7 near the west bank of the reservoir arm where there was less gravel and chat and more of the softer sediments. Consequently we were not able to determine the fine-scale depositional patterns of metals that enter from Short Creek.

The large hill of gravel and chat slopes gently from the east bank to the west bank of the Spring River arm (see Figure 7). It is most pronounced at the point where the Short Creek water confluences with the reservoir and slopes gently both up-reservoir and down-reservoir of a small island and promontory that has formed near the confluence. The sediment characteristics of Short Creek just upstream of the point of confluence with the Spring River arm are similar to the material that comprises the hill in the reservoir. Based upon this evidence it is our conclusion that most or all of the gravel and chat material of the hill has been derived from erosion of mine wastes from the Galena mining area. This material has been transported downstream by the erosive action of Short Creek and has been deposited in the reservoir.

The sediments at the deepest point near the center of sample site 8 were composed of gravel with some material that appeared to be similar to chat. It is not known if the chat-like material at sample site 8 originated from the

Short Creek watershed or whether this material simply represents the sediment characteristics of the old Spring River bed previous to the inception of mining activities in Galena. In the shallower areas near the east and west banks at this sample site the sediments consist of fine muds and clays.

The sediments near the breastworks of the Riverton Dam consist of large amounts of gravel and chat-like material, especially in the area that conforms to the old Spring River bed. It is not clear if the chat-like material was derived from the Short Creek watershed but the shallow depths of the water near the breastworks suggests that this material was transported to the site. Perhaps it represents fill material deposited during construction of the dam. There is an accumulation of fine muds and clays near the north and south shores by the breastworks.

The Shoal Creek arm of the reservoir is different from Spring River arm in cross-sectional configuration. At sample sites 9 and 10 the arm is broader than in the Spring River arm and there are extensive shallower areas to the north and south of the old river bed at site 9 and an extensive shallow area near the north bank at site 10. The river channel is near the south bank at site 10 and the bottom sharply drops-off. The river channel sediments at site 10 were gravels with only small accumulations of fine sediment. The river channel at site 9 consisted of fine sediments that extended deeper than the Ekman Dredge penetrated.

There was extensive accumulation of fine sediments near the breastworks of the Lowell Dam. No gravel or chat-like material was detected. We presume that the fine sediments cover the sediments of the old river channel at this sample site.

Sample site 11 consists of the common area of Empire Lake. The substrates of this area consist almost exclusively of fine organic sediment and clays. They are quite well developed and extend to a depth deeper than the Ekman Dredge would sample. Based upon the metals analysis (which is discussed in a subsequent section of this report) we conclude that these sediments could have resulted in part by extensive deposition of suspended material that has entered the common area from the arms of the reservoir.

Analytical Results of Sediment Analyses

An attempt was made to obtain historical data to compare with the results of this study. A review of the literature indicates that very little information is available regarding the analysis of sediments of reservoirs in Kansas. Therefore, any evaluation of current data is difficult.

In 1973, the National Uranium Resource Evaluation (NURE) Program was established by the U.S. Atomic Energy Commission, now the U.S. Department of Energy (DOE). The main purpose of this program was to provide a comprehensive in-depth assessment of the nation's uranium resources for national energy planning and to identify areas favorable for uranium resources. This was a massive study that covered the entire United States. The NURE Program consisted of five parts, one of which provided some data that can be compared with data obtained in the current study. The part of the program that is of direct interest to our study is the Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) Program. This program was to provide analytical data on surface water, groundwater, stream sediment, and lake sediment.

One of the areas covered in the NURE study was the Joplin quadrangle (Anonymous, 1979a) in southeast Kansas. Included in this quadrangle is the

Empire Lake area and all of the streams which feed into it, directly or indirectly. It is unfortunate, however, that the data in the NURE report does not include data on the cadmium and lead content of the sediments sampled. However, the data pertaining to the manganese and zinc concentrations in the sediments correlates very well and tends to verify the findings reported in this study. For example, some results from the NURE report show the following:

> Two samples taken from different locations in Short Creek contain 1,486 and 1,681 ppm manganese respectively and 942 and 3,446 ppm zinc respectively.
>
> A sample from Shoal Creek was analyzed and found to have 2,074 ppm manganese and 1,260 zinc.
>
> A sample from an upper arm of the Spring River contained 546 ppm manganese and 5,960 ppm zinc.
>
> A sample from Center Creek in Missouri that feeds into the Spring River was found to contain 927 ppm manganese and 1,081 ppm zinc.

It should be noted that all of the samples were taken from streams or tributaries that drain the eastern portion of the area under study. As stated above, these analyses for manganese and zinc correlate very well with the analyses for those elements reported in the current study.

By contrast, however, it can be noted that for streams feeding into Spring River from the west and north, the levels of manganese and zinc are much lower and the concentrations closer to those at other locations in Kansas which are discussed later in this section. As examples, the following are noted:

> A sample from Brush Creek has concentrations of 372 ppm manganese and 74 ppm zinc.
>
> A sample from an unnamed feeder stream into Shawnee Creek contains 281 ppm manganese and 128 ppm zinc.
>
> A sample from Cow Creek has concentrations of 796 ppm manganese and 63 ppm zinc.

These results reinforce the importance of one of the stated objects of the second part of our study which is to begin this summer, namely the need to take samples where Cow Creek, Center Creek and Turkey Creek confluence with the arm of Spring River. Additionally, consideration might be given to taking some samples from Brush Creek. Even though this creek feeds the Spring River below the dam of Empire Lake, the analytical results from the NURE report would seem to indicate that it could possibly serve as a "control" location for the area.

While the NURE report does not contain data for cadmium and lead in the sediments from the area, experience would indicate that concentrations of these elements would be on the same order of magnitude as those determined in this study. The correlation coefficients that we have calculated for zinc and cadmium and lead lend additional support to this conclusion.

Two other parts of the NURE report were reviewed to obtain data from other areas of Kansas for comparative purposes. Data from the Manhattan quadrangle (Anonymous, 1979b) and the Dodge City quadrangle (Anonymous, 1980) are cited here.

The Manhattan quadrangle is in the north central part of the state. Included in this quadrangle are Tuttle Creek and Milford reservoirs. The Tuttle Creek reservoir is located on the Big Blue River and is fed by many smaller creeks and streams such as Clear Creek and Fancy Creek. The Milford Reservoir is located on the Republican River and fed by other smaller streams such as Quimby Creek. The Republican and Blue Rivers eventually flow into the Kansas River, part of which flows through the southern part of the quadrangle. The Chapman River is also located in the western part of the quadrangle. Sediment samples from the two reservoirs and all of the streams mentioned above were analyzed and data for manganese and zinc show a remarkable consistency.

With one exception, the manganese values range from a low of 275 ppm to a high of 652 ppm. The values for zinc range from a low of 41 ppm to a high of 78 ppm.

The Dodge City quadrangle is, of course, located in the southwest part of the state. The Arkansas River and the Cimarron River along with several small creeks such as Bear Creek and Crooked Creek are located within this area. In addition to data on manganese and zinc, analytical data on sediments collected from these streams included values for lead. Manganese values for samples collected from this area range from a low of 285 ppm to a high of 722 ppm. The values for zinc range from a low of 26 ppm to a high of 84 ppm. The values for lead range from 11 to 31 ppm.

It is of some significance to note that the analytical data from these two quadrangles for manganese and zinc are quite consistent. It would be incorrect to assume that these data are typical of all other areas of Kansas. The data we have generated for this report from samples collected from the Empire Lake area show that values for manganese are somewhat higher and values for zinc are considerably higher than the two areas cited above. We believe an obvious conclusion that can be drawn is that the mineral deposits and past mining activity in the Galena area have contributed to the elevated concentrations of the four elements in the sediments which are the subject of study in this report.

The data on the lead concentrations in the sediments from the Dodge City quadrangle are helpful for comparative purposes. These data compare quite favorably with some data from a limited number of analyses of soil samples from the northeastern part of Kansas (Galle and Welch, unpublished data). The data obtained from a few samples which represent several different soil horizons show values ranging from 10 to 40 ppm. As can be seen, the concentrations of lead in the sediments from Empire Lake are quite high when compared to the values in the sediments from the Dodge City quadrangle and the soil samples cited above. Again, an obvious conclusion is that the lead and zinc mining in southeast Kansas is a contributing factor in the much higher concentrations of lead in the sediments that were analyzed for this study.

The values for cadmium on the same soil samples cited in the previous paragraph run from 0.2 to 1.0 ppm. Given the consistency of the concentrations of manganese, zinc and lead in other areas of the state, it would be safe to assume that cadmium would follow the same pattern. The observed values for cadmium in the sediments from Empire Lake are all quite high when compared with the limited data cited above.

Metals Concentration in Sediments

Chemical analysis of surface waters entering the Spring River arm of Empire Lake have indicated high concentrations of cadmium, lead, manganese and zinc in solution and associated with suspended solids (Anonymous, 1984, 1985; KDHE, 1980, Ferrington, unpublished data). Based upon these data we predicted that the sediments of at least the Spring River arm would contain concentrations of metals that were elevated over background levels. Cow Creek, Center Creek and Turkey Creek all contribute metals to the Spring River upstream of Empire Lake and we expected that the sediments at sample sites 1-3 would reflect these inputs. We expected that there would be sharp increases in the metals concentrations at the point of confluence by Short Creek and that the concentrations of metals down-reservoir of this point would either drop sharply or slowly decrease depending upon the sedimentation rates and sediment movement characteristics within the reservoir. We also expected that the metals concentrations in sediments of the Shoal Creek arm would be much less than in the Spring River arm. We based this prediction upon the lack of perennially flowing streams confluencing with the Shoal Creek arm from the mined areas west of Galena.

The data from the May samples, which are presented in this report, has shown that all sample sites in the reservoir have elevated levels of all four metals. There are three deviations from our expected patterns that need to be considered in more detail. They are:

(1) The Shoal Creek arm of the reservoir has higher concentrations of metals than expected.

(2) The common area of Empire Lake exhibits the highest average concentrations of cadmium, lead and zinc.

(3) There is no consistent pattern of sharp increase in concentrations for the metals at sample sites 4-7, where Short Creek confluences with the Spring River arm.

The sources of the metals in the Shoal Creek arm of the reservoir could not be identified with our field design. Since we had expected that the metals concentrations would be low and that the sample sites in this arm could serve as control sites we did not sample as extensively in this arm as in the Spring River arm. Without any field data for the concentrations of metals in sediments up-reservoir of our sample sites we can only speculate about possible sources. We have reviewed quadrant maps of the Shoal Creek arm and offer our preliminary thoughts as to the origin of the metals in the sediments.

Our review of the maps shows that there are no perennially flowing streams that drain mined areas and confluence with Shoal Creek upstream of sample site 10. There are five intermittent or ephemeral streams that originate in or near mined areas and confluence with Shoal Creek upstream of sample site 10. Two of these intermittent streams originate in the tailings areas west and south west of Galena, a distance approximately 1.5 linear miles due west of Schermerhorn Park. The two streams are unnamed and were always dry when visited by one of us (LCF) on several occasions in the recent past (1984-1986).

There are three intermittent streams that confluence with Shoal Creek approximately 1.5 to 2.9 miles linear distance due east of the Kansas-Missouri border at the latitude of Schermerhorn park. These streams drain a mined area south of Joplin and occur in Roaring Spring Hollow, Gordon Hollow and Tanyard Hollow. These streams have never been visited by any of us and the surface flow conditions thus remain unknown.

Based upon the map reconnaissance of the Shoal Creek watershed it must be concluded that movements of metals out of tailings areas via one or more of these intermittent streams are responsible for the elevated metals concentrations in sediments of the Shoal Creek arm of the reservoir. Additional sediment sampling will be necessary in order to further resolve the inputs of metals by these two potential sources. It is our understanding that sediment samples have been or will be collected near the bridge on Highway 26 at Schermerhorn Park in association with planned bridge renovation activities. Results from these samples may assist in resolving the sources of metals to the sediments of the Shoal Creek arm.

The common area of Empire Lake has the highest average concentrations of cadmium, lead and zinc of all the sample areas that we investigated. This was not expected, <u>a priori</u>, but can be logically explained by two mechanisms. Additional field collecting will be necessary to discriminate between the two.

The first mechanism that we offer to explain the high concentrations of metals in the common area is that the soils of the common area were high in metals concentrations from geologic causes and that the current concentrations are a reflection of the natural soil chemistry of the area. In this scenario there would have been little or no accumulation of metals due to transport within the reservoir and through deposition of suspended material with elevated amounts of metals adhering to them. It would also follow that the metals concentrations in the soils immediately adjacent to Empire Lake would show very similar elevated levels of metals, and the vertical profiles of metals for lake sediments and adjacent soils would match.

The second mechanism to explain the high concentrations of metals is that the metals have been or continue to be elevated in the common area as sediments from both arms are deposited by sediment movement and depositional patterns within the reservoir. In this scenario one would predict that the metals that enter the reservoir in solution from Short Creek, Turkey Creek, Center Creek and other sources precipitate out of solution or rapidly become complexed with suspended clays or other particulate matter. Currents within the reservoir would then transport the particulate-bound metals downstream and would deposit them in the common area as water circulates within the common area and current velocities are reduced due to increased drag in the shallow areas. If this mechanism is operating then one would expect to see a sharp decrease in the metals concentrations of the soils immediately surrounding the reservoir, and vertical profiles of metals from the two different areas would be very different.

The lack of a sharp increase in the average metals concentrations of sediments at sample sites 3-7 near the confluence with Short Creek provides additional support for the second mechanism offered above. The lack of a sharp increase in metals concentrations near a known source suggests that precipitation and or settling-out of particle bound metals is not a rapid and rather static phenomenon within the Spring River arm of the reservoir. Rather, it appears as if there is substantial movement of suspended material and possibly even more coarse sediments within the arm due to water movement and wind disturbances. If this is so then one would predict that the incoming metal load would be more homogeneously distributed down-reservoir of the input points and that there would be accumulations of metals-laden sediments in eddy areas and other backwaters that may serve to trap suspended materials and allow for settling and deposition to occur. More research need to be done to determine the substrate movement rates and sedimentation patterns within Empire Lake in order to better understand the phenomena underlying our observed patterns of metals concentrations associated with sediments.

Species Richness, Relative Abundance and Estimates of Standing Crop Densities of Aquatic Macroinvertebrates

In order to make the most meaningful comparisons of pollution-related changes in aquatic macroinvertebrates it is necessary to select appropriate controls and contrast composition, relative abundances and standing crop densities between the control and impacted areas. If no representative control areas are available then comparisons with existing literature can be made, but by necessity comparisons can only be made of general patterns and community characteristics rather than more rigorous species-by-species comparisons that one would prefer. In this study we anticipated that the sample sites in the Shoal Creek arm and perhaps even up-reservoir of the confluence by Short Creek in the Spring River arm could serve as legitimate controls. For reasons already discussed these sites are not appropriate. Therefore, we use existing literature for preliminary discussions of richness, abundance and densities of aquatic macroinvertebrates in Empire Lake. When appropriate we make contrasts among different sites in our study in succeeding paragraphs.

No quantitative data collected in a manner similar to our field design for other reservoirs in Kansas are available to us for comparison. Recent studies by Griffith and Welker (1987) at Cheyenne Bottoms in central Kansas and Canton et al. (unpublished, but abstract and personal communication available in April 1987) at Lake Ogallala, Nebraska and a past study by Sublette (1957) for Lake Taxoma along the Texas-Oklahoma border provide the geographically closest comparisons. Other studies at more distant sites are by Cowell and Vodopitch (1981), Peterka (1972), Tebo (1955), and Uutala (1981). The lakes or reservoirs in these studies are situated in Florida, Iowa, North Dakota and New York. There are many additional studies in the literature, but since the intention here is to give the reader a general feel for patterns of species richness and standing crop densities of aquatic macroinvertebrates in lentic habitats rather than provide an exhaustive review of lake and reservoir studies, it is felt that the above cited studies will serve to effectively illustrate such patterns.

Table 14 shows the species richness estimates and range or average of standing crop densities of aquatic insects for the above cited publications. As can be seen from the table, both species richness and standing crop densities can be highly variable from habitat to habitat. Based upon these data and others that we have gleaned from the literature it would seem that a minimum of 30-45 species of aquatic insects should be present in a reservoir with good water quality and an absence of toxic pollutants associated with the sediments. It is also to be expected that minimum standing crop density estimates should be on the order of 2,500 to 6,000 or more aquatic insects per square meter. These conclusions indicate that overall standing crop densities of macroinvertebrates have been substantially depressed for the entire reservoir, but species richness values have not been as drastically affected when considered for the reservoir as a whole.

TABLE 14. Summary of species richness and standing crop densities of aquatic insects from selected studies.

Study	Lake	Region	Species Richness	Standing Crop Densities Per Square Meter
Cowell & Vodopitch (1981)	Lake Thonotosassa	FL	42	7424 (2255-12,255)
Canton et al. (1988)	Lake Ogallala	NE	70	-- (6400-66,000)[4]
Griffith & Welker (1987)	Cheyenne Bottoms	KS	--	-- (4,857-65,082)[7]
Peterka (1972)	Lake Ashtabula	ND	--	(1831-2622)[6]
Sublette (1957)	Lake Texoma	TX,OK	70	2500 (900-4,300)[3]
Tebo (1955)	Lizard Lake	IO	41	(1517-4,108)[5]
Uutala (1981)	Deer Lake	NY	33[2]	-- (6220-10,940)
Uutala (1981)	South Lake[1]	NY	20[1,2]	-- (2740-6,030)

1 - Lake with reduced pH
2 - Only includes species of Chironomidae, other benthic insect species not counted
3 - Estimated from graph in publication
4 - No mean value given. Values for densities of limnetic zone not included in range estimate
5 - Range of means reported for various depths and substrate types
6 - Range of means reported for 3 monthly sample periods in summer
7 - Only includes species of Chironomidae, other benthic insect species not counted. Range is for six samples taken during winter, spring and mid-summer.

A final word of caution is needed at this point. It should be noted that the above conclusions are reached based upon literature values. These studies were conducted in other regions of the country, using other field designs and differing collecting methods and sorting strategies. We would feel more confident in our conclusions if comparisons could be made for other reservoirs in southeastern Kansas, in particular ones that are considered to be representative of high water quality and high habitat quality. Unfortunately we have not been able to locate such data for comparison purposes. We feel that this further underscores the need for basic studies in unstressed or higher water quality habitats so that appropriate base line data can be generated to serve as background when attempting to evaluate the effects of heavy metals or other classes of pollutants in aquatic systems within Kansas.

The dominant groups of aquatic macroinvertebrates collected in this study were Diptera (76.5%), Oligochaeta (14.4%) and Ephemeroptera (8.4%). Within the Diptera the Chironomidae were most abundant (68.5% of all organisms collected). From the perspective of percentage composition these patterns are quite typical of what would be expected for a shallow water reservoir. Based upon an analysis of the abundance patterns of major taxonomic groups it must again be concluded that the presence of high concentrations of metals in the sediments has not caused major shifts in community composition.

Considered at the generic level, one finds that the numerically dominant insect taxa are *Procladius* spp. (2 species), *Hexagenia* sp., *Chironomus* sp., *Tanypus* spp. (2 species), *Cryptochironomus* sp., *Chaoborus* sp., *Polypedilum* spp. (2 species), and *Ablabesmyia annulata*. All of these genera are common and widespread species that are commonly collected from reservoirs both in Kansas (Ferrington, unpublished data) and elsewhere (e.g., see Cowell and Vodopitch, 1981; Sephton and Paterson, 1986; Sublette, 1957). One must again conclude that even when considered at the generic level there is no evidence to suggest that major taxonomic change in the benthic fauna has occurred as a result of metals concentration in the reservoir.

From the perspective of standing crop densities, however, there is reason to conclude that the metals have resulted in reduced standing crop densities of aquatic macroinvertebrates. As indicated earlier, review of the literature leads us to expect that minimum estimates for standing crop densities should be on the order of 2,500-6,000 individuals per square meter. The values that we calculated never approximated this expected range, and in all cases but one were less than 775 organisms/sq. meter; or less than 31% of the minimum value of our expected range (see Table 15). The reductions in standing crop densities appear to occur for all taxa that were collected. For instance, *Procladius* spp., which was comprised of two species and was the dominant genus of aquatic macroinvertebrate collected by us exhibited a range of densities from 14.4 to 872.8 individuals/sq. meter across the 12 sample sites. Species of this genus often attain very high densities which can exceed 4,000 individuals/sq. meter (Sephton and Paterson, 1986).

TABLE 15. Distribution of species and standing crop densities with regard to sample sites in Empire Lake, May samples.

Sample Site	Number of Samples	Species Richness	Mean Number per sq. meter	95% Confidence Interval
1	6	22	498	35-960
2	6	17	418	169-668
3	6	11	454	220-688
4	6	17	663	215-1113
5	6	16	541	34-1048
6	6	16	454	74-834
7	6	15	772	323-1221
8	6	13	317	228-406
9	6	9	238	117-359
10	6	21	714	454-975
11	6	13	1810	-2-3623[A]
12	6	13	433	-54-919[A]

A - 95% Confidence interval includes zero. The variance of the individual sample values is so high that inaccurate estimates of the mean may have resulted.

Although we were not able to estimate standing crop biomass for this study, we did develop some preliminary relationships that relate size to biomass for selected species found in this study. It is anticipated that during subsequent research we will be able to estimate biomass values for our samples and will be able to analyze in more detail the effects that the metals have upon standing crop biomass.

In our original design for this research project we anticipated that increasing concentrations of the metals, especially cadmium and zinc, would have the consequence of reducing both species richness and standing crop density. This prediction was based upon laboratory tests of toxicities of cadmium and zinc to aquatic insects and other literature already cited. We also proposed that we would develop linear models of cause and effect which would relate the decreases in richness and densities to some (unknown) function of the metals concentrations. This approach will be discussed in more detail in a subsequent section, but it is necessary to provide an overview of it here in order to continue the discussion of patterns of species richness and standing crop densities.

From our results it is clear that there is no simple linear relationship between metals concentration and species richness or standing crop densities of aquatic macroinvertebrates of Empire Lake. To the contrary, we observed the highest standing crop densities at sample site 11, which had the highest average concentrations of cadmium, lead and zinc in the sediments. No consistent pattern was seen for species richness versus metals concentrations either when all 70 samples were considered, irrespective of sample site or depth. In order to interpret these trends and to look for other underlying relationships we re-analyzed our data by sorting according to depth.

The results of our analysis of species richness and standing crop densities versus depth showed a significant effect. Both species richness and standing crop densities showed maximum values at depth category 2, which corresponds to depths equal to or greater than one meter but less than two meters. Species richness at shallower depths was slightly less, and it dropped off in a consistent manner at depth categories 3-7. Standing crop densities at the shallowest depth category was 349 individuals/sq. meter, which was roughly equivalent to the density observed at depth category 6. Intermediate densities at categories 3-5 were very similar and ranged from 529-612 individuals/sq. meter. The minimum density estimate was obtained for depth category 7.

Patterns of density versus depth similar to ours are commonly reported in the literature (Sublette, 1957; Harper and Cloutier, 1986, and references contained therein). It has been suggested that the pattern is due to disturbance by wave action in the littoral zone and shallow waters surrounding it and to lowered oxygen concentrations that occur at increased depths. This hypothesis seems to us to be a tenable mechanism to explain density patterns versus depth and we feel that it is likely to be the explanation for the patterns that we observe. It then must be concluded that depth is a primary factor affecting species richness and standing crop densities of aquatic macroinvertebrates in Empire Lake.

After identifying depth as a primary factor affecting richness and density we proceeded to test for linear effects of metals concentrations upon richness and density within each depth category. A discussion of these analyses is included in subsequent sections.

It was also anticipated that species diversity values would show a negative relationship to increasing metals concentrations. No relationship was found so we checked to see if there was a relationship between evenness values and metals concentrations. One would expect that if increasing concentrations of metals represent increasing stress on the macroinvertebrate communities then the evenness component of diversity would decrease and a negative association with metals concentrations would be observed. There was no statistically significant correlation observed for evenness and metals concentration among our data.

Regression Analyses

Linear regression analyses were performed in order to check for significant linear effects of metals concentrations on either species richness or standing crop densities. Analyses using all 70 samples did not show significant linear relationships. This was unexpected but can be explained by the depth effect that we have documented. Since all 70 samples represent various depths, and since the depth effect is pronounced, potential underlying relationships of metals concentrations to richness and density could easily be masked.

We next attempted to regress average metals concentrations (taken one metal at a time) versus average richness and/or average density when sorted by depth category. We observed no significant linear effects of metals concentration upon richness and abundance versus depth. This was surprising at first but can be explained in the following manner. We first analyzed the concentrations of the metals versus depth by ANOVA and found that there is no statistical difference in the concentrations of cadmium, lead and zinc at different depths. Manganese showed a statistically significant depth effect, but the densities are curvilinear, not linear, with regard to depth. These analyses show that (1) cadmium, lead and zinc cannot be used to predict values (i.e. independent variables) since they show no significant pattern with depth, and (2) manganese should not be used as a predictor value (independent variable) in a linear model since it shows a curvilinear relationship to depth.

In a final attempt to elucidate potential patterns of cause and effect we reasoned that there may be linear relationships among metal concentrations and richness or density within a given depth class. We sorted the data to depth and then performed a regression analysis for each metal for each of the depth classes 1-6 versus richness and versus density.

From this last group of analyses we observed statistically significant negative linear relationships for the concentrations of cadmium, lead and zinc versus richness and density at depth category 1. The negative relationship is consistent with what we would predict based upon toxicity studies. However, from the same set of analyses, we found a statistically significant positive effect of cadmium, lead and zinc on density at depth category 2 and a positive affect of manganese on richness and density at depth category 3. The relationships are the reverse of what toxicity data suggest and we cannot offer a mechanism to explain these effects at this time, other than to speculate that there may be some underlying effects of sediment composition that we have not considered. One of the objectives of our second year study is to analyze our sediments for particle size composition and to incorporate these results into our models.

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APPENDIX

[illegible]

[illegible] Integer Data

	e	Log Base 2	10
Total Units	69.000		
Total Taxa	22		
Taxa per Unit Measure	0.319		
Gleason's Index	5.196	3.602	11.964
Margalef's Index	4.960	3.438	11.420
Menhinick's Index	2.649		
McIntosh's Index	0.776		
Simpson's Index	0.038		
maximum	0.481		
minimum	0.032		
V evenness	0.124		
V' evenness	0.183		
redundancy	0.8[illegible]0		
Simpson's Complement	0.[illegible]12		
maximum	0.968		
minimum	0.519		
V evenness	0.87[illegible]		
V' evenness	0.942		
redundancy	0.124		
Simpson's Reciprocal	11.[illegible]88		
maximum	31.280		
minimum	2.080		
V evenness	0.319		
V' evenness	0.364		
redundancy	0.681		
Shannon's (H')	2.622	3.783	1.139
maximum	3.085	4.451	1.340
minimum	1.541	2.223	0.669
V evenness	0.700		
V' evenness (J')	0.850		
redundancy	0.200		
equitability (E)	0.364		
Standard Deviation	3.550		
maximum	10.020		
minimum	0.351		
scaled	0.669		
Brillouin's (H)	2.246	3.240	0.975
maximum	2.647	3.818	1.149
minimum	1.239	1.788	0.538
V evenness	0.715		
V' evenness (J)	0.840		
redundancy	0.285		
Number of Moves	3[illegible]5.000		
maximum	4[illegible].000		
scaled	0.[illegible]37		

[illegible]

[illegible] Integer Data

	Log Base e	2	10
Total Units	5[illegible].000		
Total Taxa	16		
Taxa per Unit Measure	0.276		
Gleason's Index	3.940	2.731	9.073
Margalef's Index	3.694	2.561	8.506
Menhinick's Index	2.101		
McIntosh's Index	0.655		
Simpson's Index	0.171		
maximum	0.546		
minimum	0.047		
V evenness	0.246		
V' evenness	0.31[illegible]		
redundancy	[illegible]		
Simpson's Complement	[illegible]		
maximum	0.953		
minimum	0.454		
V evenness	0.752		
V' evenness	0.870		
redundancy	0.248		
Simpson's Reciprocal	5.[illegible]41		
maximum	21.192		
minimum	1.[illegible]		
V evenness	[illegible]		
V' evenness	0.[illegible]76		
redundancy	0.7[illegible]		
Shannon's (H')	2.17[illegible]	3.[illegible]36	0.[illegible]45
maximum	2.[illegible]	[illegible].967	1.200
minimum	1.272	1.[illegible]35	0.5[illegible]2
V evenness	[illegible].606		
V' evenness (J')	0.[illegible]87		
redundancy	0.[illegible]94		
equitability (E)	0.375		
Standard Deviation	5.[illegible]52		
maximum	10.500		
minimum	0.500		
scaled	0.525		
Brillouin's (H)	1.854	2.675	0.805
maximum	2.378	3.431	1.033
minimum	1.016	1.466	0.441
V evenness	0.615		
V' evenness (J)	0.780		
redundancy	0.385		
Number of Moves	[illegible]24.000		
maximum	[illegible]85.000		
scaled	0.214		

[illegible]

[illegible] Column: [illegible] Integer Data

		Log Base	
	e	2	10
Total Units	63.000		
Total Taxa	10		
Taxa per Unit Measure	0.159		
Gleason's Index	2.414	1.673	5.558
Margalef's Index	2.172	1.506	5.002
Menhinick's Index	1.260		
McIntosh's Index	0.539		
Simpson's Index	0.269		
maximum	0.733		
minimum	0.096		
V evenness	0.[illegible]3		
V' evenness	0.3[illegible]		
redundancy	0.717		
Simpson's Complement	0.731		
maximum	[illegible]		
minimum	[illegible]		
V evenness	[illegible]717		
V' evenness	0.7[illegible]		
redundancy	0.283		
Simpson's Reciprocal	3.713		
maximum	11.625		
minimum	1.365		
V evenness	0.229		
V' evenness	0.319		
redundancy	0.771		
Shannon's (H')	1.718	2.479	0.746
maximum	2.300	3.318	0.999
minimum	[illegible]	1.045	0.314
V evenness	0.631		
V' evenness (J')	0.747		
redundancy	0.369		
equitability (E)	0.400		
Standard Deviation	5.932		
maximum	10.760		
minimum	0.433		
scaled	0.461		
Brillouin's (H)	1.512	2.181	0.657
maximum	2.054	2.963	0.892
minimum	0.582	0.840	0.253
V evenness	0.632		
V' evenness (J)	0.736		
redundancy	0.369		
Number of Moves	160.000		
maximum	226.000		
scaled	0.298		

[illegible]

[illegible] Integer Data

	Log Base		
	e	2	10
Total Units	9[illegible].000		
Total Taxa	[illegible]		
Taxa per Unit Measure	0.174		
Gleason's Index	3.539	2.453	8.148
Margalef's Index	3.317	2.299	7.638
Menhinick's Index	1.668		
McIntosh's Index	0.578		
Simpson's Index	0.225		
maximum	0.699		
minimum	0.053		
V evenness	0.266		
V' evenness	0.321		
redundancy	0.734		
Simpson's Complement	0.775		
maximum	0.947		
minimum	0.301		
V evenness	0.734		
V' evenness	0.816		
redundancy	0.266		
Simpson's Reciprocal	4.453		
maximum	19.027		
minimum	1.431		
V evenness	0.172		
V' evenness	0.234		
redundancy	0.823		
Shannon's (H')	2.015	2.907	0.875
maximum	2.770	3.996	1.203
minimum	0.886	1.279	0.385
V evenness	0.599		
V' evenness (J')	0.727		
redundancy	0.401		
equitability (E)	0.313		
Standard Deviation	9.809		
maximum	19.000		
minimum	0.447		
scaled	0.495		
Brillouin's (H)	1.790	2.583	0.777
maximum	2.490	3.592	1.081
minimum	0.724	1.045	0.314
V evenness	0.604		
V' evenness (J)	0.719		
redundancy	0.396		
Number of Moves	424.000		
maximum	546.000		
scaled	0.223		

[illegible] DIVERSITY VALUES [illegible] LAKE TRANSECTS

Data column: trans 1 Integer Data

	Log Base e	2	10
Total Units	75.000		
Total Taxa	14		
Taxa per Unit Measure	0.187		
Gleason's Index	3.243	2.248	7.466
Margalef's Index	3.011	2.087	6.933
Menhinick's Index	1.617		
McIntosh's Index	0.465		
Simpson's Index	0.338		
maximum	0.681		
minimum	0.059		
V evenness	0.447		
V' evenness	0.486		
redundancy	0.5[illegible]3		
Simpson's Complement	0.662		
maximum	0.941		
minimum	0.319		
V evenness	0.553		
V' evenness	0.704		
redundancy	0.447		
Simpson's Reciprocal	2.962		
maximum	16.818		
minimum	1.467		
V evenness	0.097		
V' evenness	0.176		
redundancy	0.903		
Shannon's (H')	1.512	2.182	0.657
maximum	2.635	3.802	1.144
minimum	0.906	1.307	0.393
V evenness	0.351		
V' evenness (J')	0.574		
redundancy	0.649		
equitability (E)	0.286		
Standard Deviation	10.909		
maximum	16.303		
minimum	0.497		
scaled	0.341		
Brillouin's (H)	1.312	1.892	0.570
maximum	2.345	3.384	1.019
minimum	0.734	1.058	0.319
V evenness	0.359		
V' evenness (J)	0.559		
redundancy	0.641		
Number of Moves	344.000		
maximum	374.000		
scaled	0.080		

COMMUNITY DIVERSITY VALUES FOR ENTIRE LAKE TRANSECTS

Data Columns: trans6 Integer Data

	Log Base e	2	10
Total Units	63.000		
Total Taxa	15		
Taxa per Unit Measure	0.238		
Gleason's Index	3.620	2.510	8.336
Margalef's Index	3.379	2.342	7.751
Menhinick's Index	1.890		
McIntosh's Index	0.624		
Simpson's Index	0.194		
maximum	0.602		
minimum	0.052		
V evenness	0.258		
V' evenness	0.322		
redundancy	0.742		
Simpson's Complement	0.806		
maximum	0.949		
minimum	0.398		
V evenness	0.742		
V' evenness	0.850		
redundancy	0.258		
Simpson's Reciprocal	5.153		
maximum	19.147		
minimum	1.661		
V evenness	0.200		
V' evenness	0.269		
redundancy	0.700		
Shannon's (H')	2.066	2.981	0.897
maximum	2.704	3.901	1.174
minimum	1.116	1.610	0.485
V evenness	0.598		
V' evenness (J')	0.764		
redundancy	0.402		
equitability (E)	0.400		
Standard Deviation	6.304		
maximum	12.394		
minimum	0.414		
scaled	0.508		
Brillouin's (H)	1.780	2.569	0.773
maximum	2.357	3.401	1.024
minimum	0.896	1.293	0.389
V evenness	0.605		
V' evenness (J)	0.755		
redundancy	0.395		
Number of Moves	249.000		
maximum	31[illegible].000		
scaled	0.217		

Integer Data

		Log Base	
	e	2	10
Total Units	106.000		
Total Taxa	14		
Taxa per Unit Measure	0.132		
Gleason's Index	3.002	2.081	6.913
Margalef's Index	2.788	1.932	6.419
Menhinick's Index	1.360		
McIntosh's Index	0.674		
Simpson's Index	0.145		
maximum	0.769		
minimum	0.063		
V evenness	0.116		
V' evenness	0.189		
redundancy	0.884		
Simpson's Complement	0.855		
maximum	0.937		
minimum	0.231		
V evenness	0.884		
V' evenness	0.912		
redundancy	0.116		
Simpson's Reciprocal	[illegible]		
maximum	1[illegible].900		
minimum	1.301		
V evenness	0.383		
V' evenness	0.434		
redundancy	0.617		
Shannon's (H')	2.144	3.093	0.931
maximum	2.637	3.804	1.145
minimum	0.687	0.991	0.298
V evenness	0.747		
V' evenness (J')	0.813		
redundancy	0.253		
equitability (E)	0.429		
Standard Deviation	3.401		
maximum	24.558		
minimum	0.514		
scaled	0.672		
Brillouin's (H)	1.953	2.818	0.848
maximum	2.411	3.479	1.047
minimum	0.565	0.815	0.245
V evenness	0.752		
V' evenness (J)	0.810		
redundancy	0.248		
Number of Moves	375.000		
minimum	174.000		
scaled	0.347		

[illegible] ENTIRE LAKE TRANSECTS

[illegible] trans 2   Integer Data

	Log Base e	Log Base 2	Log Base 10
Total Units	44.000		
Total Taxa	12		
Taxa per Unit Measure	0.273		
Gleason's Index	3.171	2.198	7.302
Margalef's Index	2.907	2.015	6.693
Menhinick's Index	1.809		
McIntosh's Index	0.665		
Simpson's Index	0.168		
maximum	0.556		
minimum	0.063		
V evenness	0.212		
V' evenness	0.301		
redundancy	0.788		
Simpson's Complement	0.832		
maximum	0.937		
minimum	0.442		
V evenness	0.785		
V' evenness	0.688		
redundancy	0.212		
Simpson's Reciprocal	5.950		
maximum	15.767		
minimum	1.792		
V evenness	0.298		
V' evenness	0.377		
redundancy	0.702		
Shannon's (H')	1.988	2.868	0.863
maximum	2.476	3.573	1.075
minimum	1.162	1.676	0.505
V evenness	0.628		
V' evenness (J')	0.803		
redundancy	0.372		
equitability (E)	0.417		
Standard Deviation	4.271		
maximum	9.238		
minimum	0.492		
scaled	0.568		
Brillouin's (H)	1.679	2.422	0.729
maximum	2.107	3.040	0.915
minimum	0.915	1.320	0.397
V evenness	0.641		
V' evenness (J)	0.797		
redundancy	0.359		
Number of Moves	123.000		
maximum	160.000		
scaled	0.231		

[illegible]

[illegible] trans 9 Integer Data

	Log Base e	2	10
Total Units	33.000		
Total Taxa	8		
Taxa per Unit Measure	0.242		
Gleason's Index	2.288	1.586	5.268
Margalef's Index	2.002	1.388	4.610
Menhinick's Index	1.393		
McIntosh's Index	0.696		
Simpson's Index	0.155		
maximum	0.616		
minimum	0.099		
V evenness	0.110		
V' evenness	0.252		
redundancy	0.890		
Simpson's Complement	0.845		
maximum	0.[illegible]		
minimum	0.384		
V evenness	0.890		
V' evenness	0.937		
redundancy	0.110		
Simpson's Reciprocal	6.439		
maximum	10.164		
minimum	1.625		
V evenness	0.564		
V' evenness	0.634		
redundancy	0.436		
Shannon's (H')	1.866	2.691	0.810
maximum	2.079	2.996	0.902
minimum	0.930	1.341	0.404
V evenness	0.816		
V' evenness (J')	0.898		
redundancy	0.184		
equitability (E)	0.625		
Standard Deviation	2.949		
maximum	8.839		
minimum	0.354		
scaled	0.694		
Brillouin's (H)	1.572	2.269	0.683
maximum	1.758	2.537	0.764
minimum	0.721	1.040	0.313
V evenness	0.821		
V' evenness (J)	0.894		
redundancy	0.179		
Number of Moves	44.000		
maximum	84.000		
scaled	0.476		

[illegible]

[illegible] 10 Integer Data

	Log Base		
	e	2	10
Total Units	99.000		
Total Taxa	20		
Time per Unit Measure	0.20[illegible]		
Gleason's Index	4.352	3.017	10.022
Margalef's Index	4.135	2.866	9.521
Menhinick's Index	2.010		
McIntosh's Index	0.654		
Simpson's Index	0.154		
maximum	0.651		
minimum	[illegible]		
V evenness	[illegible]		
V' evenness	[illegible]		
redundancy	[illegible]		
Simpson's Complement	[illegible]		
maximum	[illegible]		
minimum	[illegible]		
V evenness	0.814		
V' evenness	[illegible]		
redundancy	0.186		
Simpson's Reciprocal	6.494		
maximum	24.750		
minimum	1.535		
V evenness	0.214		
V' evenness	0.262		
redundancy	0.786		
Shannon's (H')	2.294	3.309	0.996
maximum	2.995	4.320	1.301
minimum	1.054	1.521	0.458
V evenness	0.639		
V' evenness (J')	0.766		
redundancy	0.361		
equitability (E)	0.350		
Standard Deviation	7.619		
maximum	17.665		
minimum	0.224		
scaled	0.576		
Brillouin's (H)	2.036	2.937	0.884
maximum	2.677	3.862	1.162
minimum	0.863	1.245	0.375
V evenness	0.646		
V' evenness (J)	0.760		
redundancy	0.354		
Number of Moves	579.000		
maximum	741.000		
scaled	0.219		

[illegible] LAKE [illegible]

[illegible] trans 11 Integer Date

	Log Base e	2	10
Total Units	256.000		
Total Taxa	12		
Taxa per Unit Measure	0.047		
Gleason's Index	2.164	1.500	4.983
Margalef's Index	1.984	1.375	4.568
Menhinick's Index	0.750		
McIntosh's Index	0.480		
Simpson's Index	0.300		
maximum	0.916		
minimum	0.0[illegible]0		
V evenness	0.26[illegible]		
V' evenness	0.327		
redundancy	0.737		
Simpson's Complement	0.700		
maximum	0.920		
minimum	0.084		
V evenness	0.737		
V' evenness	0.761		
redundancy	0.263		
Simpson's Reciprocal	3.335		
maximum	10.535		
minimum	1.092		
V evenness	0.196		
V' evenness	0.266		
redundancy	0.804		
Shannon's (H')	1.588	2.290	0.689
maximum	2.485	3.585	1.079
minimum	0.280	0.404	0.122
V evenness	0.593		
V' evenness (J')	0.639		
redundancy	0.407		
equitability (E)	0.333		
Standard Deviation	36.139		
maximum	70.437		
minimum	0.492		
scaled	0.490		
Brillouin's (H)	1.510	2.179	0.656
maximum	2.384	3.440	1.035
minimum	0.237	0.343	0.103
V evenness	0.593		
V' evenness (J)	0.633		
redundancy	0.407		
Number of Moves	1031.000		
maximum	1326.000		
scaled	0.222		

[illegible] LAKE [illegible]

[illegible] Column: [illegible] 12 Integer Data

	e	Log Base 2	10
Total Units	39.000		
Total Taxa	11		
Taxa per Unit Measure	0.282		
[illegible]'s Index	3.003	2.081	6.914
[illegible]'s Index	2.730	1.892	6.285
[illegible]'s Index	1.761		
[illegible]'s Index	0.771		
[illegible]	[illegible]		
[illegible]	0.548		
minimum	[illegible]		
[illegible] evenness	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
[illegible]	[illegible]		
redundancy	[illegible]		
[illegible]	[illegible]		
maximum	[illegible]		
minimum	1.625		
V evenness	0.634		
V' evenness	0.68[illegible]		
redundancy	[illegible]		
Shannon's (H')	[illegible]	3.214	0.96[illegible]
maximum	[illegible]	3.44[illegible]	1.037
minimum	1.160	[illegible]	0.5[illegible]4
[illegible]	[illegible]		
V' evenness (J')	0.9[illegible]		
redundancy	0.1[illegible]		
equitability (E)	[illegible]		
Standard Deviation	2.2[illegible]		
maximum	8.442		
minimum	0.522		
scaled	0.782		
Brillouin's (H)	1.877	2.708	0.815
maximum	[illegible]	2.908	0.875
minimum	0.907	1.309	0.394
V evenness	0.875		
V' evenness (J)	[illegible]		
redundancy	0.125		
Number of Moves	[illegible]		
maximum	[illegible]		
scaled	[illegible]		

The University of Kansas Medical Center

School of Medicine
Department of Preventive Medicine

March 25, 1988

RECEIVED
MAR 25 1988
REMD SECTION

Alice Fuerst
Waste Management Division
U.S. Environmental Protection Agency
Region VII
726 Minnesota Ave.
Kansas City, KS 66101

Dear Ms. Fuerst:

Thank you for sending me the materials on the Operable Unit Feasibility Study for Galena.

I would like to share with you a few additional thoughts on your project.

1. The EPA level of effort on potential food chain contamination could be improved. Warren Bird, a graduate student in the Civil Engineering Department at KU in Lawrence has some additional data on fish in Empire Lake. I'm sure that he will be glad to share the data with you. These fish were analyzed at the EPA laboratory. What is completely missing, however, is any analysis of a sample of garden vegetables. Cadmium is a notorious food chain contaminant and certain crops (eg., spinach and tomatoes) can accumulate this metal to high concentrations.

2. It could be helpful if your study could be accomplished at greater speed. With metals now known to be around, it is important to quickly ascertain the extent of the problem in the remaining areas of Cherokee County.

3. The jurisdictional problems with Missouri and Oklahoma need to be cleared up quickly. Effort should be made to start your work in Jasper County. If there are obstacles to this, then you need to address them vigorously through administrative or political channels. With respect to Oklahoma, the state needs to evaluate the tailing piles for heavy metals. Alternatively, EPA Region VI should take over. The EPA administrator may need to take action to insure that this set of interstate problems is resolved expeditiously.

In conclusion, I think that your study has come a long way. However, more needs to be accomplished. I hope that my comments will provide some constructive guidance.

Godspeed.

Sincerely,

John S. Neuberger

John S. Neuberger, Dr. P.H.
Associate Professor

JSN/jt